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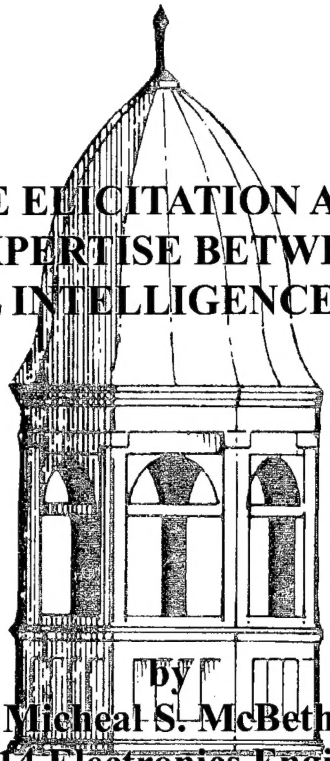
KNOWLEDGE ELICITATION AND LEARNING TO TRANSFER EXPERTISE BETWEEN GENERATIONS OF NAVAL INTELLIGENCE ANALYSTS



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As an Advanced Research Project

This paper was completed as an independent research project in the Advanced Research Department, Center for Naval Warfare Studies, Naval War College. It is submitted to the faculty of the Naval War College in partial satisfaction of the academic requirements for the degree of Master of Arts in National Security and Strategic Studies. As an academic study completed under faculty guidance, the contents of this paper reflect the author's own personal views and conclusions, based on independent research and analysis. They do not necessarily reflect official current policy in any agency of the U.S. government.

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ABSTRACT

This study seeks to address the problem of how to transfer expertise between generations of Naval intelligence analysts. Expertise refers to the tacit and explicit knowledge that senior analysts call upon to perform intelligence analysis. Transfer refers to the process of "passing on" knowledge from senior analysts to those who will replace them. Transfer also refers to adaptive expertise where a new generation of analysts apply their freshly-learned knowledge in flexible and creative ways. Lessons are drawn from the literature on knowledge management, the science of learning, human information processing, and experience from selected knowledge preservation projects in government organizations. These lessons are used to construct a model of knowledge preservation, building on a simplified model of knowledge transfer derived from the concepts of logical depth and exformation. A three-pronged model, based on how long senior analysts are available to work face-to-face with their replacements, emerges from this approach. A case is made to adopt a story-centered approach to learning. Ideas for putting this model into action at the Office of Naval Intelligence are presented. The practical issues of cost, schedule, and cultural acceptance are addressed.

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ACKNOWLEDGEMENTS

This study report is dedicated to my wife Elaine. Her love and encouragement have given me the heart to take chances and expand my boundaries. Her understanding and sacrifice have freed me to study uninterrupted at the Naval War College for the better part of a year while she dealt with contractors building a garage in our backyard, a car that left her stranded, and a heating system that left her without heat and hot water.

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Fortune has shined upon me as I have worked, studied, and played in a magical place with a spirit of innovation that has long been integral to the proud history and traditions of the U.S. Navy.

EXECUTIVE SUMMARY

According to a 1998 report on the health of Scientific and Technical (S&T) intelligence, analysts at the Office of Naval Intelligence (ONI) averaged over 21 years of experience. One consequence of this graying of the work force is an impending loss of knowledge and expertise as these senior analysts retire; the accumulated knowledge residing in their heads will walk out the door with them.

The problem facing ONI is to transfer as much of this knowledge as practical from senior analysts to their replacements. The aspiring analysts on the learning end of this transaction have different educational backgrounds and work experiences. Since people tend to learn most effectively by building on existing knowledge and experiences, proposed knowledge preservation solutions need to take these individual differences into account. These analysts begin their learning journeys at different starting points. The senior analysts on the transmitting end of this transaction will not retire on the same day; they will be on hand to pass their knowledge on for different periods of time. Proposed solutions need to take advantage of the time available.

The three-pronged knowledge preservation model presented in this study takes into account the starting point of analysts learning their craft and the time available for senior analysts to impart their knowledge. For senior analysts with more than three years before retirement, traditional mentoring is the preferred approach, since there is no substitute for the one-on-one interaction between mentor and mentee. For senior analysts with one to three years before retirement, a "hand-off" method is the preferred approach since there is insufficient time for traditional mentoring but enough time for deep and substantive interaction between retiring experts and learners. In the hand-off method, learners build and explain case studies based on

senior analysts' knowledge and experiences. This process encourages newer analysts to learn with understanding since they will have to explain and teach the lessons of the case study. For senior analysts with less than a year before retirement, an "over-the-wall" method is the preferred approach since there is insufficient time for direct human interaction but important knowledge can still be captured in a form that fosters learning with understanding. In the over-the-wall method, a digital video archive of stories is created that can be searched and viewed from a learner's desktop.

These three learning strategies overlap and can be used independently or together. It may make sense for some senior analysts to engage in all three methods before they retire. Analysts are engaged in traditional mentoring today at ONI. These mentoring relationships should be encouraged and strengthened. Learner-built case studies are similar, in principle, to the "vignette" sessions where analysts explain foreign weapon systems to the admiral. In fact, it is suggested to use vignettes as a forum for learners to explain the case studies they build. The use of digital video for knowledge preservation will be a new practice at ONI, but there is plenty of precedence for its use at the National Weapons Laboratories.

Several ad hoc knowledge preservation initiatives are being pursued at ONI. These initiatives and the inertia behind them can propel the three-pronged model described in this study report into a thriving knowledge preservation program. The time to act is now. Make knowledge preservation a priority. Redirect the resources required and invest in the future. The U.S. Navy's future Naval intelligence capability is at stake.

SECTION I

INTRODUCTION

An enemy cruise missile streaks across the sea. Traveling several times the speed of sound and weaving in an erratic manner it throws a rooster tail of salt water thirty feet in the air as it passes within forty feet of the wave caps below. Designed to penetrate U.S. point defenses and carrying a 750 lb warhead, the missile's large size and hypervelocity make its kinetic energy alone great enough to devastate its intended target, a U.S. cruiser seventy miles over the horizon.

A countermeasure leaps from the sea quickly flying to intercept the missile's flight trajectory. In position fifteen miles in front of the incoming missile, it waits six seconds before detonating an explosive charge to create a high power microwave beam aimed at the weaving missile, its massive rooster tail now visible on the horizon. The microwave beam acts like a shotgun blast of electrical energy that couples into the missile's guidance section instantly fusing the attitude control circuitry. The missile, still moving a mile every second, slams into the sea filling the sky with a shower of salt water and metal fragments from the disintegrating weapon.

Although clearly a fictional story, such a scenario is plausible if its elements exist in the future, say the year 2015. It is a good bet the enemy cruise missile will exist, but will the analytical capability to devise countermeasures to defeat it? Today, the U.S. has an edge against potential adversaries, in part, because of the expertise of its Naval intelligence analysts. In the near future, many of these analysts will retire and their knowledge and expertise will leave with them unless steps are taken to capture and preserve their knowledge.

In the past, one generation of intelligence analysts succeeded another without much direct attention from upper management and little fanfare. Individual analysts entered the business in a "sink or swim" fashion. They learned the business through on-the-job training. Some experts

believe it takes 6-8 years of experience before a new S&T analyst has the expertise necessary to produce top notch analysis.[1] During the cold war, a steady stream of these analysts were "moving up the ranks." That picture has changed in recent years. Now there are mostly newer analysts with a few years of experience and senior analysts with 15 or more years of experience.

This study report represents my attempt to identify practical ways to transfer the expertise-related knowledge of retiring Naval intelligence analysts to their successors.

Roadmap to the Study. I begin with a discussion of an aging workforce and the impending loss of expertise across the Department of Defense and within Naval intelligence. This sets the stage for providing the reader with the motivation for pursuing this topic by sketching out the dimensions of the problem, consequences of not addressing the problem, and the inherent difficulties of crafting a solution to the problem. From here, the problem is carefully stated to capture the essence of the situation facing decision makers at ONI. An elegant solution that solves the wrong problem is of little value. After clearly defining the problem, the study moves on to consider lessons that can be drawn from industry, academia, and government. These lessons touch on knowledge management, the science of learning, and experience from selected knowledge preservation projects in government organizations. Drawing on these lessons, a knowledge preservation model, based on how long senior analysts are available to work face-to-face with their replacements, is developed. The next section considers ideas for putting the model into action at ONI. The practical issues of cost, schedule, and cultural acceptance are addressed. Finally, the study ends with a discussion of areas for future work and some concluding remarks.

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[1] William B. Scott, "Intelligence Complex Admits Need for Outside Technical Talent," *Aviation Week and Space Technology*, April 30, 2001, pp. 75-76.

SECTION II

MOTIVATION

DoD has been in a sustained period of civilian workforce reductions since fiscal year 1989, and additional reductions are expected at least through fiscal year 2005. The issue of aging workforce and its potential to adversely affect future mission accomplishment is one that has been with DoD since the beginning of its downsizing, and it remains an issue today.

--Michael Brostek and Barry Holman
United States General Accounting Office[2]

The net effect is a workforce that is not balanced by age or experience and that puts at risk the orderly transfer of institutional knowledge. Although we cannot say what the appropriate balance between younger and older employees should be, the continuing increase in the number of retirement-age employees could make it difficult for DoD to infuse its workforce with new and creative ideas and develop the skilled civilian workers, managers, and leaders it will need to meet future mission requirements.

--Henry L. Hinton, Jr.
United States General Accounting Office[3]

Widespread Problem. The Department of Defense (DoD) faces a crisis within its civilian workforce. The trends are clear. Insufficient numbers of workers are in the pipeline to fill the shoes of their more-experienced counterparts who will soon be eligible for retirement. Failure to emphasize long-range planning during past downsizings, shifting demographics, and competition for talented workers all contribute to the problem. Workforce reductions were accomplished without careful consideration of the skills and expertise that were lost through early retirements, and hiring rates were insufficient to keep an adequate number of successors in the pipeline. Demographic changes mean there are fewer workers available to replace all the

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[2] General Accounting Office, *Human Capital: Strategic Approach Should Guide DoD Civilian Workforce Management* (GAO/T-GGD/NSIAD-00-120, March 9, 2000), p. 4.
[3] General Accounting Office, *Human Capital: Major Human Capital Challenges at the Departments of Defense and State* (GAO-01-565T, March 29, 2001), p. 8.

retiring baby boomers. This situation can be traced to differences in birth rates between the generations.[4]

An Aging Workforce at Naval Intelligence. The Office of Naval Intelligence (ONI) is facing an impending loss of knowledge and expertise for the same reasons as the rest of DoD. According to a 1998 report on the health of Scientific and Technical Intelligence, analysts at ONI averaged over 21 years of experience. The report points out the need to "capture remaining knowledge before it is permanently lost."[5] Some of the challenges facing ONI are highlighted in the following passage quoted from the report's conclusion.

> Analysts stretched thin have no time for mentoring the few new S&T employees and no time for their own professional development (assuming funds were available). The civilian analysts, in particular, are an aging cadre, many of whose formal academic training was decades ago and whose functional areas are experiencing exponential growth.[6]

The problem of an aging workforce has been recognized at ONI and across DoD. The General Accounting Office, the Office of Personnel Management, and DoD have performed studies and initiated programs to combat its negative effects. Many of these efforts have emphasized the need for every agency to adopt structured workforce planning as a strategy to align their workforce with their future mission.

Although the next few years will see a loss of expertise and knowledge as older workers retire, it also can be a time for DoD's civilian workforce to be infused with new ideas and new

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[4] Baby boomers have been defined as those born between 1946 and 1964. As an example, Susannah Figura cites birth rates of 25.3 births per 1,000 people in 1954 versus 14.8 in 1973. See Susannah Zak Figura, "Leadership Void: Experienced Executives Are a Vanishing Breed," *Government Executive*, September 1999. <http://www.govexec.com/features/> [April 27, 2002].
[5] Scientific and Technical Intelligence Committee, "The Health of Scientific and Technical Intelligence: A Study Conducted by the Scientific and Technical Intelligence Committee," April 1998. p. 7. <http://www.cia.ic.gov/dci/stic/4253483198/stic9801-1.html> [February 5, 2002].
[6] *Ibid.*, p. 8.

blood. It is an opportunity for organizations to better align their workforces with their strategic plans.

Workforce and Succession Planning. According to the Office of Personnel Management (OPM), workforce planning is "the process of ensuring that the right people are in the right place, and at the right time to accomplish the mission of the agency. Specifically, workforce planning is a systematic process for identifying and addressing the gaps between the workforce of today and the human capital needs of tomorrow."[7]

OPM created a five step workforce planning model in 1999 to help organizations understand the process. Step one sets the organization's strategic direction. In step two the organization assesses its supply and anticipated demand for workers along with discrepancies in needed skills. In step three, the organization develops an action plan. Step four swings the plan into action. And in step five, the organization monitors, evaluates, and revises workforce planning to respond to changes in the external environment and the progress made toward achieving goals.[8]

Although sometimes painful to create, putting the mission, vision, strategy, and strategic plan in writing helps to clarify them and better ensure compatibility and linkage with existing programs. These plans also provide a template which can be used to judge the appropriateness of new initiatives and programs.[9]

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[7] Office of Personnel Management, *Workforce Planning Desk Aid for Managers & Supervisors*, 1999, <http://www.opm.gov/workforceplanning/> [April 27, 2002].
[8] OPM's Workforce Planning Model is available on line.
<http://www.opm.gov/workforceplanning/wfpmodel.htm> [April 27, 2002]
[9] Dina G. Levy, et al., *Strategic and Performance Planning for the Office of the Chancellor for Education and Professional Development in the Department of Defense* (Santa Monica, CA: The RAND Corporation, 2001), pp. 7-21.

Succession planning is a form of workforce planning where leaders forecast the mix of workers and skills that will be needed in the future and then create a plan to achieve the desired future workforce. Traditional succession planning efforts start with a *supply* analysis that looks at the existing workforce and competencies and a *demand* analysis that looks at projected needs, staffing patterns, and anticipated future workload. These products flow into a *gap* analysis that compares supply and demand, looks at demographics, and identifies areas where action needs to be taken. *Solutions* are based on the results of this gap analysis. Solutions include reassignments and recruiting to manage workforce transition, employee training and development to grow the right people, and monitoring staffing patterns to keep track of relevant changes.[10]

Although planning, recruitment, and retention all contribute toward achieving the desired future workforce, it is the development of existing and new employees that commands our attention here. How can these workers learn the knowledge they will need to solve tomorrow's problems? How can the knowledge of senior workers nearing retirement be captured, preserved, and learned by workers who will fill their shoes?

Traditional Career Development for Intelligence Analysts. At ONI, civilian intelligence analysts have traditionally learned their craft through "on-the-job" training where they work on a number of projects over several years. Not everyone is cut out for intelligence work. Some people develop a passion for the business and make a career out of it while others lose interest and move on after a few years.

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[10] Cheryl Zimmerman, "After You're Gone: Succession Planning," Presentation at the Agricultural Research Service National Administrative Officers' Conference 2001, April 23-26, 2001, Colorado Springs, CO.
<http://www.afm.ars.usda.gov/AOConf2001/Files/SuccessionPlanning.ppt> [April 30, 2002]

Although a new analyst is typically paired with a more experienced analyst and assigned a project to work on, the process has been described as "sink or swim." It can take up to a year for a new analyst to begin to get a good "feel" for the work and be in a position to contribute in a meaningful way, for instance, to the discussion in a meeting. After starting as an intelligence analyst, it typically takes a total of 6-8 years before a new S&T analyst has the expertise necessary to produce top-notch analysis.[11]

The development process is made more difficult because senior analysts are in such short supply and high demand. There is insufficient time to spend coaching and mentoring younger analysts who are just learning the craft.

Time and Resource Constraints. Just as the Year 2000 or Y2K problem was impossible to postpone, so is the aging workforce problem. Every day that passes brings these senior analysts one day closer to retirement. Not only are their days numbered, a large fraction of their time left will be spent solving urgent problems rather than developing a new generation of analysts to replace them. There is a limited supply of time and money available for knowledge preservation.

Importance of Naval Intelligence. Naval intelligence has been crucial in achieving decisive combat results. The U.S. Navy's expertise in Scientific and Technical intelligence has provided an edge through understanding how enemy weapon systems work and how they can be stopped. This capability is a leverage point which can spell the difference between victory and defeat.

Summary. The problem of an aging workforce exists across DoD and at ONI. Workforce and succession planning provide a systematic approach to address this issue at the

[11] ONI representatives, Interview by author, Suitland, MD, 3 April 2002.

agency and organizational levels. Solutions depend on new workers to replace those who will be retiring. These retiring workers have a huge store of knowledge and expertise that must be passed on to the next generation. There is a limited supply of time and money available for knowledge preservation. Some areas, like Naval intelligence, are vital to our national interests and deserve special attention.

SECTION III

PROBLEM STATEMENT

> *Faced with the increased complexity and proliferation of modern weapons, intelligence organizations will be able to function efficiently in the future only by making all the necessary preparations in peace-time. The key to victory will thus depend to a large extent on the quality of scientific intelligence, an area in which the Western Democracies may have a considerable advantage if the appropriate preparations are completed.*
>
> --Michael I. Handel[12]

Given the motivation provided by an aging workforce and the resource and time constraints at ONI, is there a practical way to preserve the expertise of senior Naval intelligence analysts before most of them retire in the next few years? A solution to the problem will revolve around people—senior analysts with knowledge and habits locked in their heads and newer analysts tasked with learning old and new tricks. "It's a people-driven business," said Ken Parys, ONI's Assistant Director of Intelligence for Science and Technology. "Our strength is people who can see items that look unrelated on the surface, yet have hidden relationships and patterns that seasoned analysts can recognize," he explained.[13]

There are at least three fundamental problems which must be addressed to successfully preserve this knowledge. These are:

- **Nature of expertise.** What constitutes expertise in conducting Naval intelligence analysis and how does one identify and prioritize expertise worth preserving?
- **Capture, learning, and transfer**. How can expertise-related knowledge be captured in a form that fosters learning and transfer?
- **Practicality**. What characteristics do potential solutions need to possess to be seen as practical by analysts and senior Navy management?

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[12] Michael I. Handel, *War, Strategy, and Intelligence* (Totowa, NJ: Frank Cass & Company Limited, 1989), p. 174.

[13] Kenneth J. Parys, telephone conversation with author, 14 November 2001.

These problems are discussed in more detail below. However, before leaving this list, two points are worth noting. First, it is taken as a given that some of the skills needed to conduct intelligence analysis can be learned by methods other than direct experience. Second, this is not intended as an exhaustive list. There are a host of other problems that need to be considered. For example, how can these knowledge preservation efforts be integrated into a larger, enterprise-wide, knowledge management program at ONI? How can this knowledge be used to create automated analytic tools? How can this knowledge be used to improve the overall analytic process? What tools can best be used to capture and share expertise-related knowledge? Should outside consultants or an in-house team be used? These are all non-trivial issues and areas for productive further study. However, the three fundamental issues listed above seem to capture the essence of the problem and must be answered before more complicated questions are engaged. These answers can perhaps shed light on a host of other issues.

The Nature of Expertise in Naval Intelligence Analysis. Expertise and knowledge are slippery concepts to pin down. Experts are often at a loss to explain the source of their expertise and describe how they get their work done. Thomas Davenport and Laurence Prusak give the following working definition:

> Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents of repositories but also in organizational routines, processes and practices.[14]

How can this definition be used to identify expertise in conducting intelligence analysis? If this definition can be cast in terms of intelligence analysis then several benefits may be realized.

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[14] Thomas H. Davenport and Laurence Prusak, *Working Knowledge: How Organizations Manage What They Know* (Boston, MA: Harvard Business School Press, 1998), p. 5.

First, it will help specify expertise beyond a simple "we know it when we see it" level of recognition. Second, a more precise definition will allow a better match to be made between knowledge and learning, distinguishing those aspects that are readily learnable through particular techniques. Third, a more precise definition will help with prioritization. If one cannot distinguish A from B, then it is difficult to prioritize A over B. Finally, if certain aspects of expertise in Naval intelligence are common with those in other fields, then it is more likely that techniques that have been shown to be successful to capture, preserve, and pass on expertise in those domains will be successful in Naval intelligence.

Identifying and prioritizing expertise worth preserving. How can one identify and prioritize expertise worth preserving? Knowledge must be recognized, which relates back to the discussion on definitions above. Once knowledge is recognized as expertise-related, it must be prioritized so the most critical knowledge can be captured using the resources and time available. Finally, there is the issue of criteria for prioritization. How does one determine what is most important and valuable? Should priority be given to knowledge that is easiest to pass on or the most difficult to learn without assistance? Which of these strategies should drive the priority? Perhaps some combination of strategies should be used.

Capturing expertise-related knowledge in a form that fosters learning and transfer. How can expertise-related knowledge be captured in a form that fosters learning and transfer? It is useful to pull this question apart and consider some of the subtleties lurking in it. Expertise-related knowledge refers to "conditionalized" knowledge. That is, knowledge that includes

details of the contexts in which it applies.[15] For example, a rule of thumb needs to be captured with some information on the conditions under which to use it. The learning here needs to be thought of as "learning with understanding" versus the kinds of learning that depend on memorization of facts and rote procedures.[16] Transfer can also be used with two different meanings. The first is in the sense of "passing on" knowledge from one person to another. The second, and equally important sense, is in the notion of the "ability to extend what has been learned in one context to new contexts."[17] Transfer is related to what has been called "adaptive expertise," where the expertise can be applied in new ways and in new contexts rather just in routine situations. Adaptive expertise has been likened to the difference between an artist versus a skilled craftsman.

Two more concepts that are related to learning with understanding and transfer are *metacognition* and *pedagogical content knowledge*. Metacognition refers to the ability to monitor one's current level of understanding and decide when it is not adequate.[18] This ability is important for self-directed learning and problem solving. This aspect of knowledge needs to be made part of the capture and learning process. Pedagogical content knowledge refers to understanding the barriers that appear as stumbling blocks to those trying to acquire knowledge for the first time.[19] What are the strategies for overcoming these barriers? This may be a more difficult feature to capture than metacognition, since the experts may have long forgotten the barriers they encountered when they first acquired the knowledge.

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[15] John D. Bransford, Ann L. Brown, and Rodney R. Cocking, eds., *How People Learn: Brain, Mind, Experience, and School* (Washington, D.C.: National Academy Press, 2000), p. 43. <http://books.nap.edu/books/0309070368/html/index.html> [May 6, 2002]
[16] *Ibid.*, pp. 55-56.
[17] *Ibid.*, p. 51.
[18] *Ibid.*, pp. 47-50.
[19] *Ibid.*, p. 45.

The need for practical solutions. What features must potential solutions possess to be seen as practical by analysts and senior Navy management? This question is about considerations of use and the criteria by which solutions will be judged. The analysts' perspective is critical because if there is a mismatch here, the analysts will resist using the solution or, perhaps, not use the solution at all. Senior Navy management's perspective is critical because without their support, solutions will never see the light of day or receive the funding and attention required for success.

Candidate criteria from the analysts' perspective include: ease of use, perceived ability to improve analytical performance, time burden, and responsiveness to individual needs. Candidate criteria from management's perspective include: performance, cost, and schedule. Will the proposed solution efficiently capture and transfer information? Is the solution affordable? Can the solution be implemented in time to make a difference?

Questioning the need for knowledge preservation. Critics may question the need for knowledge preservation. "Why expend resources to do this," they ask, "when you can just hire smart people who can figure out how to conduct good analysis?" After all, nobody taught experts like R. V. Jones how to conduct analysis.[20] And analysts develop their own styles. So what makes you think that any knowledge you can capture will: a) be useful, and b) if useful, be absorbed and used by others? There is some truth in all of these points, but in the final analysis, they are moot. The following arguments explain why.

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[20] R. V. Jones has been called the father of British scientific intelligence during World War II. His exploits in unraveling the mysteries of German radar, electronic navigation aids, night fighters, and rocket programs serve as object lessons on the value of intelligence analysis. See R.V. Jones, *Most Secret War* (London, UK: Hamish Hamilton Ltd, 1978).

One option is to hire smart people to replace those retiring and let them "figure it out." However, these people are sure to "re-invent a lot of wheels" and make mistakes that could be avoided along their self-directed journeys to analytical mastery. Can we afford the time and loss of capability while a new generation learns their craft without the benefit of knowledge from those who went before them? It is true that nobody taught R. V. Jones the craft of intelligence analysis. In fact, he is credited with inventing the field of scientific and technical intelligence. But R. V. Jones was a very gifted individual, at the right place, and at the right time to make a difference. Can the U.S. afford to pin its intelligence capabilities on the good fortune of having a genius appear in the nick of time?

While it is true that analysts develop their own styles, there are certain characteristics of human psychology and analytical tradecraft that are common to all analysts.[21] Analysts can benefit from a better understanding of these characteristics without sacrificing their individuality. Additionally, the expertise required to recognize patterns and draw relationships between seemingly disparate pieces of information is a specialty that takes years to develop. If analysts learning their craft can be led away from blind alleys and dead ends toward productive lines of inquiry, by developing effective techniques for organizing information, and through skill-building exercises, it stands to reason they will have an easier time developing to their full potential.

Summary. In this section, three fundamental problems facing those who would preserve the knowledge of retiring intelligence analysts were described. They are: identifying and

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[21] For example see Richards J. Heuer, Jr., *Psychology of Intelligence Analysis* (Springfield, VA: National Technical Information Service, 1999) <http://www.cia.gov/csi/books/19104/index.html> [November 12, 2001]

prioritizing expertise; capturing, learning, and transfer of expertise; and determining features of practical solutions. Arguments challenging the need for knowledge preservation were also briefly considered. The next section examines some lessons from industry, science, and government that apply to this problem. Insights are sought by looking at these problems from two different perspectives: those of knowledge management and the science of learning. This discussion is followed by a look at some knowledge preservation projects at the National Weapons Laboratories and at the Naval Air Systems Command.

SECTION IV

LESSONS FROM INDUSTRY, SCIENCE, AND GOVERNMENT

The belief that the goals of understanding and use are inherently in conflict, and that the categories of basic and applied research are necessarily separate, is itself in tension with the actual experience of science.

--Donald E. Stokes
Pasteur's Quadrant[22]

This section begins with a look at the field of knowledge management which has had its widest application in industry and academia. The academics, mostly from business management schools, have concentrated on organizational learning and how companies can harness their intellectual capital in the form of employee knowledge to create new products and services. A theory of knowledge creation emerges from this body of work. This will provide a useful construct that will contribute to the construction of a model for knowledge preservation.

The lessons from industry come in the form of knowledge management guidelines the academics have compiled from studying dozens of projects in many different types of firms. These guidelines can be thought of as "distilled experience." While the guidelines are somewhat generic, they do provide a kind of touchstone from which to judge ideas for solutions to solve problems created by an aging workforce.

Next, results are summarized from the science of learning and the related discipline of cognitive science that bear on transferring knowledge between people. Here the message centers around learning with understanding. This includes structuring knowledge presentation so that learners can build on their pre-existing knowledge, understand the contexts where new

[22] Donald E. Stokes, *Pasteur's Quadrant: Basic Science and Technological Innovation* (Washington, DC: Brookings Institution Press, 1997), p. 12.

knowledge applies, organize their knowledge for efficient retrieval and application, and monitor the state of their own learning. These features should drive the knowledge elicitation process to capture the kinds of information that help people learn efficiently along with the factual knowledge that is required to understand a subject.

This discussion is followed by a brief look at some knowledge preservation projects at the U.S. Department of Energy (DOE) and one project at the Naval Air Systems Command. DOE's projects are focused on preserving the knowledge base needed to operate a downsized nuclear weapons complex. These efforts are worth consideration because of similarities between conditions there and at ONI. Both organizations are facing an aging workforce and both deal in a highly specialized and classified type of work. But there are differences as well. The U.S. is not designing and building nuclear weapons today, but Naval intelligence production needs to continue uninterrupted. The weapons labs are able to integrate their knowledge preservation efforts under a larger umbrella of Stockpile Stewardship, which has congressional momentum and funding, while ONI lacks the auspices of a similar program for its knowledge preservation efforts. Both similarities and differences will be discussed.

The Naval Air Systems Command has a nascent knowledge preservation program. A pilot program for FY03 is under consideration. So far results have been mixed. The difficulties knowledge workers have experienced in their limited experience will be discussed. Here the importance of pre-planning and using the right tools will be emphasized.

Finally, an attempt will be made to distill from these lessons the critical underpinnings of a knowledge preservation model for DOD civilian organizations in general and Naval intelligence in particular.

Knowledge Management. Knowledge management is an active area with a growing body of literature and research. Many companies are making knowledge management a standard practice to increase worker productivity and mitigate a shortage of knowledge workers. Researchers are working to study companies' practices to gain insights about why projects fail or succeed.[23]

Theory of Organizational Knowledge Creation. Ikujiro Nonaka and Hirotaka Takeuchi present a theory of organizational knowledge creation in their seminal book on knowledge management. Their model is based on observations of activities in several Japanese firms over many years.[24]

The gist of their theory can be understood by considering the two dimensions of knowledge creation and the four modes of knowledge conversion. Figure 1 shows the two dimensions of knowledge creation. The epistemological dimension relates to "the nature and grounds of knowledge especially with reference to its limits and validity."[25] Here knowledge falls between two extremes. On the one hand is explicit knowledge that can be written down and captured in documents in the form of words, diagrams, and procedures. On the other hand is tacit knowledge that is difficult to articulate into words and is often illustrated with examples of trying to describe how to ride a bicycle, or how to swim, or even how to recognize a person's face. "We know a person's face, and can recognize it among a thousand, indeed among a million. Yet we usually cannot tell how we recognize a face we know," said Michael Polanyi to

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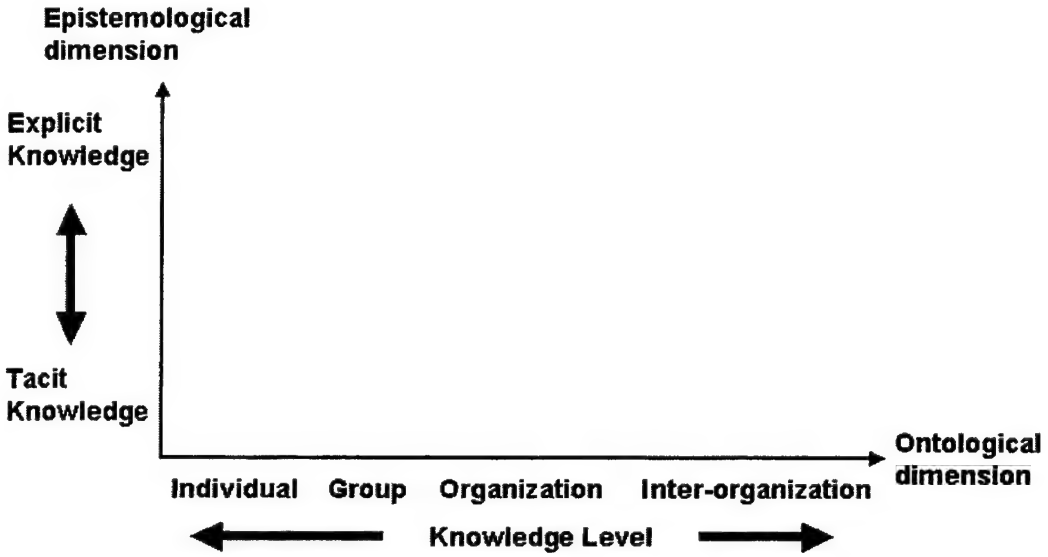
[23] Claire McInerney, "Knowledge Management – A Practice Still Defining Itself," *Bulletin of the American Society for Information Science and Technology,* February/March 2002, pp. 14-15.
[24] Ikujiro Nonaka and Hirotaka Takeuchi, *The Knowledge Creating Company: How Japanese Companies Create the Dynamics of Innovation* (New York, NY: Oxford University Press, 1995), pp. 56-94.
[25] *Webster's Ninth New Collegiate Dictionary* (Springfield, MA: Merriam-Webster, Inc., 1985), p. 419.

illustrate tacit knowledge via face recognition. "We can know more than we can tell," he

Figure 1
Two dimensions of knowledge creation



SOURCE: Adapted from Nonaka & Takeuchi (1995), p. 57.

observed.[26]

The ontological dimension relates to the existence or kinds of levels where knowledge can be found.[27] Although "knowledge originates and is applied in the minds of knowers,"[28] it can be observed at the individual, group, organization, and inter-organization levels. As the number of people interacting increases, the difficulty in communicating over space and time tends to drive the distinctions along this dimension of knowledge creation.

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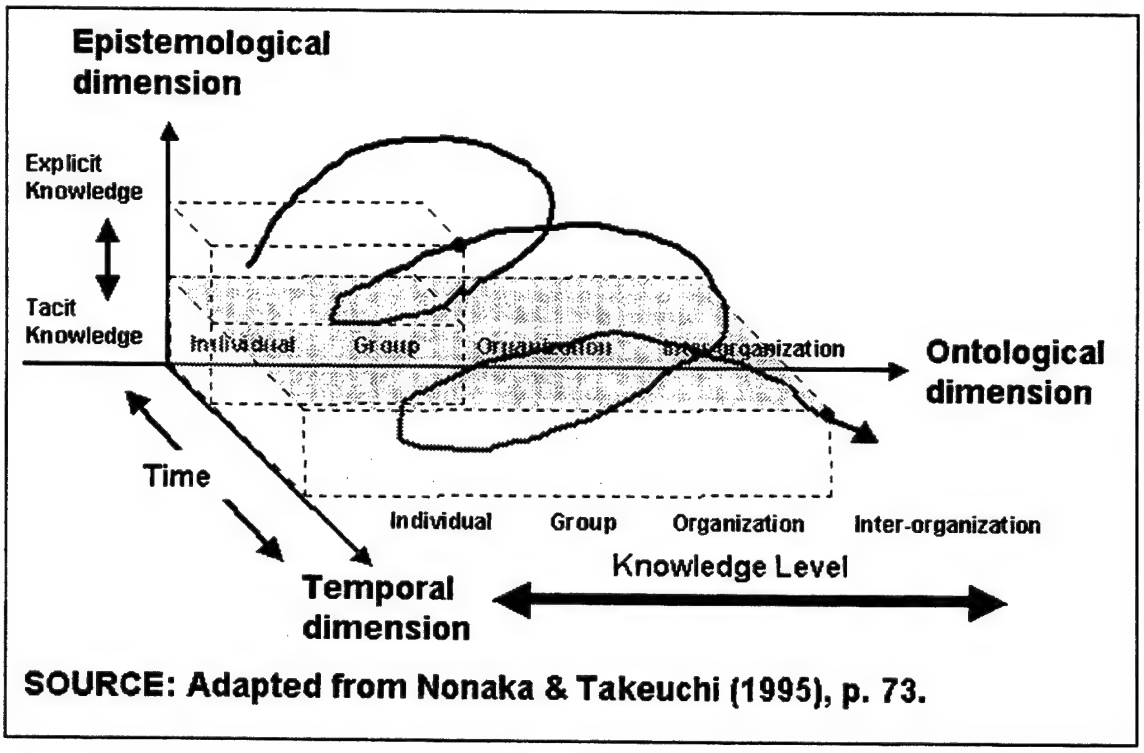
[26] Michael Polanyi, *The Tacit Dimension* (Garden City, NY: Doubleday & Company, Inc., 1966), p. 4.
[27] *Webster's*, p. 825.
[28] Davenport and Prusak, *Working Knowledge*, p. 5.

Nonaka and Takeuchi hold that the key to knowledge creation is "the mobilization and conversion of tacit knowledge" and a spiral that takes place between the epistemological and ontological dimensions.[29] Figure 2 depicts a spiral of knowledge creation that is projected

Figure 2

Knowledge Creation Spiral



forward in time as knowledge is converted from explicit to tacit and back again as it moves from individuals to groups, organization, and between organizations and back again. Nonaka and Takeuchi identify four modes of knowledge conversion: socialization, externalization, combination, and internalization. Their model of knowledge creation is "anchored to a critical assumption that human knowledge is created and expanded through social interaction between

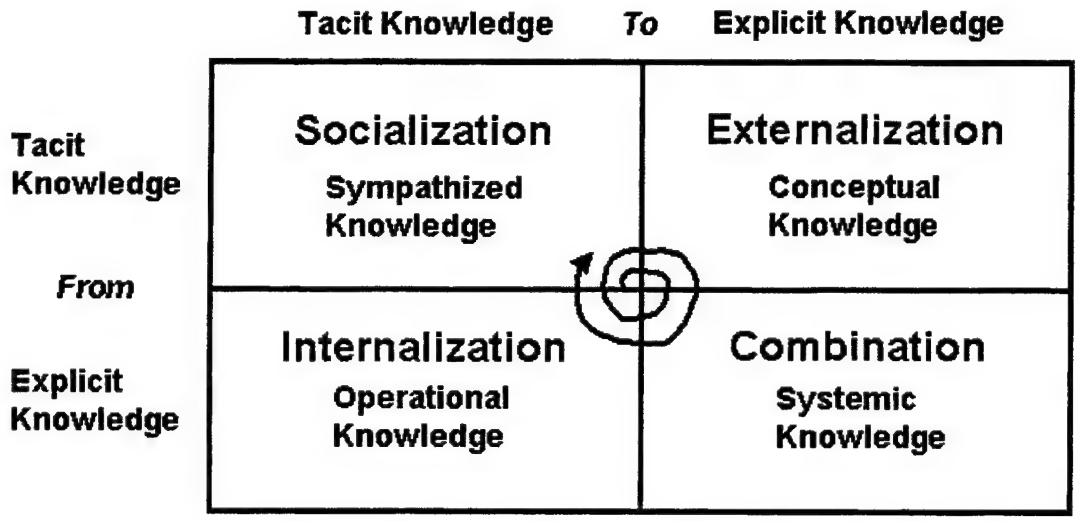
[29] Nonaka and Takeuchi, *The Knowledge Creating Company*, pp. 56-57.

tacit knowledge and explicit knowledge."[30] It is useful to examine these modes since they appear again in the discussion on the science of learning and play a role in shaping the knowledge preservation model introduced in the next section.

The four modes have names that help to generalize many specific examples into a few categories. Figure 3 illustrates the four modes of knowledge conversion and their resulting contents. These modes can also be understood in terms of everyday examples.

Figure 3

Knowledge Conversion Modes and Contents



SOURCE: Adapted from Nonaka & Takeuchi (1995), pp. 71-72.

Tacit knowledge is converted to tacit knowledge between people in the form of shared experiences. This conversion process is called *socialization*. The contents of this knowledge can be characterized as *"sympathized" knowledge* since the process implies a connection between people that transcends written and spoken language. To understand this mode of knowledge

[30] *Ibid.*, pp. 61-73.

conversion, consider what happens when two people communicate who have ridden the same roller coaster at an amusement park. When they talk to each other about the feeling of helpless anticipation one experiences near the end of the long climb to the first big drop, they can instantly relate to each other. Both have vivid memories of their experiences. When they talk to a friend who has never ridden a roller coaster, she has no vivid memories draw upon, and may be unable to share this knowledge.

Tacit knowledge is converted to explicit knowledge in the form of metaphors and analogies. This process can occur within a single person or in a larger group. This type of knowledge conversion is called *externalization*. As implied by the use of metaphor and analogy, the contents are *conceptual* and make use of knowledge people already possess to get a point across. Continuing with the roller coaster example, a person with roller coaster experience may be able to convey a sense of helpless anticipation one feels approaching the first big drop by drawing on a metaphor of being simultaneously trapped in an elevator while anticipating the feeling you get when the pit of your stomach drops as in an airplane in rough air. Although it is not the same as having been on the roller coaster, being trapped in an elevator is a common experience people have of feeling helpless and most people have experienced the pit of their stomach dropping either in an airplane flying in rough weather or on as a child on a swing set. Again the emphasis is building on what someone already knows.

Tacit knowledge is created from explicit knowledge when people "internalize" knowledge either by being able to explain "it in their own terms" or practicing a skill until it becomes second nature. This type of knowledge conversion is called *internalization*. The contents of this conversion process can be characterized as *operational knowledge*, particularly when people are learning a skill or operational procedure. This conversion process can be seen

as learning at the individual level. It also depends on building on what people already know. An example here would be the roller coaster operator learning to operate the ride by reading manuals, diagrams, and stories about potential problems like how to handle the ride on days with peak crowds.

Explicit knowledge is created from explicit knowledge when people combine knowledge from several sources. Accordingly, this type of knowledge conversion is called *combination*. The contents from this conversion process can be thought of as *systematic knowledge* and the artifacts or products can be in any form of explicit knowledge. Collecting the research to write this study report is an example of combination. A roller coaster related example, might have a design engineer combining design features from several rides to design a new coaster.

Nonaka and Takeuchi draw from several examples of innovation in Japanese companies to defend and illustrate their theory.[31] Each of these four conversion processes in knowledge creation can provide insights into how to leverage a learner's existing knowledge and why human interaction is important.

Nonaka and Takeuchi identify several enabling conditions for organizational knowledge creation. These enabling conditions include *intention*, *autonomy*, *fluctuation and creative chaos*, *redundancy*, and *requisite variety*. Nonaka defines organizational *intention* as an "organization's aspirations toward its goals"[32] Intention also provides a way for people to judge the value of information and knowledge.

Autonomy allows individuals to act as circumstances dictate. This freedom fosters creativity and lets people take responsibility for their day to day activities. Autonomy applies to

[31] *Ibid.*, pp. 95-123.
[32] *Ibid.*, p. 75.

groups as well and helps to explain why companies sometimes use a 'skunk works' approach to create new products and ideas.

Fluctuation and creative chaos are important because they "stimulate the interaction between the organization and its external environment."[33] Fluctuation implies a back and forth movement with uncertainty. When fluctuation is introduced into an organization, people's routines and habits can be interrupted creating an opportunity for sensemaking. People question their assumptions and take a fresh look at their environment and situation. Creative chaos helps to induce a sense of urgency and serves to focus people's attention on problem solving. Nonaka and Takeuchi point out that Japanese companies sometimes employ creative chaos through the purposeful use of ambiguity such as ambiguous vision statements from upper management. However, they caution that benefits from creative chaos can only occur when people have the opportunity to "reflect on their actions."[34]

Redundancy is where the common ground needed for people to communicate and learn from one another originates. It is the existence of shared information that goes beyond immediate project needs and is seen in the overlapping of boundaries and responsibilities in a group. The idea is that sharing "redundant information promotes the sharing of tacit knowledge, because individuals can sense what others are trying to articulate."[35]

The idea behind *requisite variety* is that an organization's internal diversity must match the variety and complexity of its environment in order to effectively respond to challenges. People with requisite variety can deal with many contingencies. Here access to information from through the organization can help. Other techniques to foster requisite variety include creating a

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[33] *Ibid.*, p. 78.
[34] *Ibid.*, p. 79.
[35] *Ibid.*, pp. 81-81.

flat organizational hierarchy connected with a network and undergoing frequent organizational restructurings.[36]

Now that a theory for knowledge creation has been reviewed, it is time to look at some guidelines for successful knowledge management projects. These guidelines are of interest because knowledge preservation is one form of knowledge management.

Guidelines for Knowledge Management Projects. What are the characteristics of successful knowledge management projects? Based on their study of thirty-one different projects in twenty different firms, Davenport et al. identified nine common factors of successful projects. They are:[37]

- A knowledge-oriented culture
- Technical and organizational infrastructure
- Senior management support
- A link to economics or industry value
- A modicum of process orientation
- Clarity of vision and language
- Nontrivial motivation aids
- Some level of knowledge structure
- Multiple channels for knowledge transfer

A Knowledge-Oriented Culture. A knowledge oriented culture is about employees' attitudes toward sharing information and exploring new ideas. Sometimes workers have barriers toward sharing knowledge because of fear of job loss or loss of prestige. This can occur when there is competition for resources and projects that could lead workers to fear they will be "left out" if they share their exclusive knowledge. The knowledge management project needs to fit the organization's culture. Trying to force one suite of tools on workers who are accustomed to

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[36] *Ibid.*, pp. 82-83.

[37] Davenport and Prusak, *Working Knowledge*, p. 153. Also see Thomas H. Davenport, David W. De Long, and Michael C. Beers, "Successful Knowledge Management Projects," *Sloan Management Review,* Winter 1998, pp. 43-57.

being able to choose their own tools probably will not succeed. Expectations and routines are important to develop a knowledge sharing culture. They are where the inertia resides. If people expect to share knowledge and it is a part of their daily routines, then knowledge projects can flourish. Otherwise expectations and routines have to change for knowledge projects to succeed.

Technical and Organizational Infrastructure. Projects that are able to take advantage of and leverage existing technical infrastructure have an advantage. Not only do they help defray costs by using existing networks and systems, they generally have fewer problems to resolve because others have already grappled with these problems.

Senior Management Support. Senior management support is important because they set the organization's direction. They send messages that make clear the kind of knowledge that is important to the organization. They can also help clear obstacles and roadblocks from the project's path.[38]

A Link to Economics or Industry Value. Having a link to economics or industry value almost goes without saying. The investment in time, technology, and energy required for a knowledge management project needs to be important enough to justify the effort. Dollars earned or saved are the most tangible things to look at in industry, but other indirect measures such as reduced product cycle time or increased customer satisfaction can be used as well.[39] For intelligence analysis, one might look at increased analytical capabilities and improved quality of analysis.

A Modicum of Process Orientation. Davenport and Prusak advocate taking a process perspective to help the project manager "have a good sense of his or her customer, the

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[38] *Ibid.*, p. 156.
[39] *Ibid.*, p. 157.

customer's satisfaction, and the productivity and quality of the services offered."[40] A process orientation forces one to systematically pay attention to those areas that might otherwise "slip through the cracks" with a more ad hoc approach.

Clarity of Vision and Language. Clarity of vision and language make it easier for workers to understand what the project is about and where the value is for them and the organization. Since many knowledge management related terms have several meanings, it is important to pinpoint the specifics and scope of a project to avoid confusion. It is also important to exclude unstructured data or other information that is not compatible with the project.[41]

Nontrivial Motivational Aids. Nontrivial motivational aids need to be integrated into the long-term design of a knowledge management project. "Knowledge, being intimately bound up with people's egos and occupations, does not emerge or flow easily. Employees must therefore be motivated to create, share, and use knowledge." Davenport and Prusak found examples of where short-term incentives, airline frequent-flyer mileage for instance, were not effective in getting employees to use knowledge management systems. They emphasize the use of long-term incentives tied to the performance appraisal and compensation structure and the use of highly visible awards programs.[42]

Some Level of Knowledge Structure. Successful knowledge management projects have some knowledge structure, but not too much. If the structure is too fine-grained and rigid then it becomes difficult to accommodate new forms of knowledge and new categories. If there is no structure, it becomes very difficult to find the information you are looking for, and the system

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[40] *Ibid.*, p. 157.
[41] *Ibid.*, p. 158.
[42] *Ibid.*, p. 158.

essentially becomes unusable. The fluid nature of knowledge requires that the structure be flexible and tailored to meet worker's patterns of use.[43]

Multiple Channels for Knowledge Transfer. There are at least two reasons why multiple channels of knowledge transfer make sense. First, different users have different needs. And in the case of the knowledge preservation model introduced in the next section, the experts may only be available for a limited time. Multiple channels offer one way to make better use of that time. Second, multiple channels reinforce one another. Here is an example where network channels needed to be reinforced with face-to-face meetings:

> Some of the firms that had knowledge repositories realized that they had to get contributors together in a face-to-face setting on a regular basis. In that "high bandwidth" situation, trust can be established, structures for knowledge can be developed, and difficult issues can be resolved. MIT researcher Tom Allen has found in many studies that scientists and engineers exchange knowledge in direct proportion to their level of personal contact. ... There is a strong need for what the U.S. Army calls "face time."[44]

Having discussed the characteristics of successful knowledge management projects, what are the pitfalls to avoid? Fahey and Prusak identified "the eleven deadliest sins of knowledge management" based on their study of over a hundred projects over a five-year period. The pitfalls they identified are:[45]

- Not developing a working definition of knowledge
- Emphasizing knowledge stock to the detriment of knowledge flow
- Viewing knowledge as existing predominantly outside the heads of individuals
- Not understanding that a fundamental intermediate purpose of managing knowledge is to create shared context
- Paying little heed to the role and importance of tacit knowledge
- Disentangling knowledge from its uses

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[43] *Ibid.*, p. 159.
[44] *Ibid.*, p. 159.
[45] Liam Fahey and Laurence Prusak, "The Eleven Deadliest Sins of Knowledge Management," *California Management Review*, Vol. 40, No. 3, Spring 1998, pp.265-76.

- Downplaying thinking and reasoning
- Focusing on the past and the present and not the future
- Failing to recognize the importance of experimentation
- Substituting technological contact for human interface
- Seeking to develop direct measures of knowledge

Not Developing a Working Definition of Knowledge. Not developing a working definition of knowledge relates to the success guideline about clarity of vision and language. By not having a good definition of knowledge in a project, one is vulnerable to misinterpretation and confusion stemming from ambiguous terminology. It is important to distinguish data and information from knowledge. Data and information are usually not directly related to personal beliefs and values or "derived from minds at work," while knowledge always originates at a personal level.[46]

Emphasizing Knowledge Stock to the Detriment of Knowledge Flow. Emphasizing knowledge stock to the detriment of knowledge flow is really about the need to achieve a balance in the efforts to collect and store knowledge with efforts to disseminate and make knowledge accessible. This guideline brings to mind an image of dam filled to capacity while crops in fields downstream shrivel and wilt due to lack of water. Fahey and Prusak describe how viewing knowledge in terms of information can lead to a "stock-oriented" mentality. They also point out how knowledge is dynamic and alive in the community of people it originates in and therefore view flow more as a ongoing interchange like tidal waters versus the downstream flow of a river.[47]

Viewing Knowledge as Existing Predominately Outside the Heads of Individuals. Viewing knowledge as existing predominately outside the heads of individuals can lead to two

[46] Davenport and Prusak, *Working Knowledge*, pp. 2-6.
[47] Fahey and Prusak, "The Eleven Deadliest Sins of Knowledge Management," pp. 266-67.

types of problems. The first comes from disregarding the fact that knowledge originates in a knower's mind and derives its context, meaning, and value from human use. Although knowledge can reside in documents and be embedded in processes and routines, it is inextricably linked with human thought and action. The second type of problem involves a tendency to elevate data and information beyond their limits.

> Yet organizations seem to view knowledge as if it has a life of its own. They dub strikingly mundane databases as "knowledge bases," they talk of search engines as if they were human brains, and they extol executive expert systems as if the human mind were incidental to their construction and use. This attempt to dress up decades old technologies and concepts in new "knowledge" clothing is one of the more serious distractions faced by knowledge advocates[48]

Not Understanding Shared Context. Not understanding that a fundamental intermediate purpose of managing knowledge is to create shared context gets at the idea that *knowledge requires a connection between people.* People have a shared context when they achieve a shared understanding of the world and its many connections. Their shared understanding is built on common mental models which result from experiences, reflection, and dialogue. These activities take time. Fahey and Prusak view dialogue as "not just discussion but the presentation and consideration of different views and perspectives with the purpose of developing a distinctly different or new view or perspective."[49] In other words, it is the dialogue that creates knowledge. A static snapshot, frozen in time, captured in a knowledge "stock" diminishes in value.

Paying Little Heed to Tacit Knowledge. Paying little heed to the role and importance of tacit knowledge is a mistake that is easy to make. Tacit knowledge is hard to get your arms around. Tacit knowledge is, by definition, not easily expressed in words. So much of our tacit

[48] *Ibid.*, p. 267.
[49] *Ibid.*, p. 268.

knowledge is taken for granted, it is easy to lose sight of how much we depend on it to perform. Echoing a central theme from Nonaka and Takeuchi's theory of knowledge creation, Fahey and Prusak state that: "tacit knowledge is the means by which explicit knowledge is captured, assimilated, created, and disseminated."[50] Fahey and Prusak attribute the failure to attend to tacit knowledge to project managers' lack of understanding and appreciation for the interaction between tacit and explicit knowledge. Fearing that tacit knowledge is "inaccessible and impossible to influence," they often downplay and de-emphasize the tacit dimension. This can cause their efforts to achieve results strictly through explicit knowledge to stall.[51]

Disentangling Knowledge From Its Uses. Disentangling knowledge from its uses is another pitfall related to the need for balance. Project managers guilty of committing this sin spend too much effort perfecting the technical aspects of refining and organizing the data and information at the expense of focusing on relevance and the ability to influence decisions and strategic direction. They miss the forest for the trees.

Downplaying Thinking and Reasoning. Downplaying thinking and reasoning is a pitfall intimately linked to an organization's culture. On the one hand, Americans have been raised in an educational system where clear thinking and the ability to reason effectively have not been emphasized.[52] This can result in workers who never learned to write clearly, and therefore exhibit muddled thinking, flawed logic, and faulty assumptions as they struggle to

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[50] *Ibid.*, p. 268.
[51] *Ibid.*, p. 269.
[52] William Zinsser discusses this problem and one solution to it based on "writing around the curriculum" where learning to write (and think clearly) is extended beyond traditional English classes. Students take specially designed courses in subjects from economics to chemistry where writing and thinking about the elements of good writing are a central part of the learning experience. See William Zinsser, *Writing to Learn: How to Write—and Think—Clearly About any Subject at All* (New York, NY: Harper & Row, Publishers, 1988), pp. 42-51.

create knowledge products. On the other hand, deeply held beliefs and assumptions can act as a barrier to keep managers from seeing signs of changing conditions and considering their impact. Thinking and reasoning are important because people reach different states of knowledge through reasoning, for example, in a process that leads to changes in a product's design based on designers thinking and reasoning about how customers actually use the product.[53]

Not Focusing on the Future. Focusing on the past and the present and not the future is a pitfall that stems in part from the difficulty of projecting knowledge into the future and in part from a misunderstanding of the relationship between knowledge and the future. It is much easier to collect knowledge and information from the past and present than it is to make judgments about the future. Scenario planning is one technique that has been used help identify and frame possible future situations. "If the intent of knowledge is to inform and influence decision making, then its focus must be on the future. Although we cannot know the future, every strategy, decision, and action is, by definition, premised upon some view of the future."[54] Most knowledge preservation projects have limited resources. To be successful, projects must focus on the future relevance of the knowledge being preserved.

The Importance of Experimentation. Failing to recognize the importance of experimentation can handicap a project's ability to create new knowledge since experiments are often essential to validate new ideas and explore new techniques for solving problems. Fahey and Prusak point out how documenting best practices can sometimes serve to inhibit future

[53] Fahey and Prusak, "The Eleven Deadliest Sins of Knowledge Management," pp. 270-71.
[54] *Ibid.*, pp. 271-72.

improvements to these practices (to avoid updating the documentation) and caution about the tendency to emphasize exploitation over exploration of new knowledge.[55]

Substituting Technological Contact for Human Interface. Substituting technological contact for human interface can be a natural tendency with network technologies such as email and web servers and with a workforce distributed in different locations. While these tools provide convenience and access, they lack the "high bandwidth" interaction of one-on-one contact between people needed to create the shared context so critical to successful knowledge projects.[56]

Seeking to Develop Direct Measures of Knowledge. Finally, expecting all benefits of knowledge management to be captured by a few, direct measures may cause knowledge efforts to be canceled before they "pay off" or encourage managers to change their focus to "make the numbers look better." For instance, instead of measures of access "hits" and database statistics, the focus needs to be on outcome-based measures that look at activities, consequences and results.[57] Of course, these broader measures are difficult to design and probably will still not easily capture all the project's benefits.

Encouraging the nine factors of successful projects while avoiding the eleven pitfalls increases the likelihood that a knowledge preservation project will be successful. Recognizing the pitfalls is one thing, learning how to avoid them is another. However, these guidelines can serve as a useful checklist from which to judge the knowledge preservation model presented in the next section.

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[55] *Ibid.*, p. 272.
[56] *Ibid.*, p. 273.
[57] *Ibid.*, pp. 273-74.

Having introduced a theory of knowledge creation in commercial settings and discussed guidelines for knowledge management projects, the attention now shifts to consider lessons the science of learning has to offer for crafting knowledge preservation solutions.

The Science of Learning. Results from cognitive science on how the mind works are helping to move from learning practices based on speculation to ones underpinned by science. Some of these results offer lessons for knowledge preservation efforts aimed at capturing the expertise of retiring experts. What it means for one to learn with understanding is a key result.

Learning with understanding implies more than just being able to recite a mass of disconnected facts and solve test problems in a classroom setting. When one understands a subject, one is able to size up problems and frame them from different vantage points. One is also able to think clearly enough about the subject to explain it to other people. Understanding is difficult to study in people, so cognitive scientists have turned to the study of experts and expertise to gain insights into what understanding entails. Researchers have found that to solve problems, experts depend on a rich body of knowledge which must be organized around important concepts, and the knowledge must be "contextualized" to specify the limits of its applicability.[58]

One of the developments in cognitive psychology that has a direct bearing on knowledge preservation is an increased understanding of how experts differ from novices. This research has shown that experts are able to solve problems through fluent retrieval of pertinent facts and the

[58] Summaries of this research with references to the original sources include Bransford et al., *How People Learn*, pp. 8-9, pp. 31-50 and Daniel Reisberg, *Cognition: Exploring the Science of the Mind 2nd Ed.* (New York, NY: W. W. Norton & Company, 2001), pp. 466-468.

distinctive ways in which their knowledge is organized.[59] A knowledge preservation effort must pay particular attention to these details and seek ways to elicit them to get learners on the right track to develop similar skills and ways of organizing knowledge.

Another area where research results are of interest deals with learning and transfer and how to structure learning experiences so people are able to use what they learn in new settings. This encourages learners to step back, look at the big picture, and to notice patterns. Approaching an initial problem statement as a point of departure and an opportunity for exploration is another trait learners should strive for. The ability to monitor and evaluate one's own current level of understanding is also critical to the flexible application of knowledge in new situations.[60] All of these areas of research relate to what it takes for people to learn with understanding.

Another finding of relevance to knowledge preservation is that the new knowledge people learn must be constructed from and combined with their existing knowledge. This means that a learner's existing knowledge, beliefs, and preconceptions strongly influence the learning process. The degree to which this existing knowledge is engaged and challenged determines the depth of understanding reached with the new knowledge.[61]

Since understanding is important, learners need to "take control of their own learning" to monitor when they understand a subject and when they need more material and practice. This

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[59] Bransford, et al., *How People Learn,* p. 4. Differences between the organization of knowledge in novices and experts help to explain why novices often base their problem solving strategies on a problem's surface features while experts see through surface features to more important underlying principles. For an example involving how novices and experts solve inclined plane physics problems see Bransford, et al., *How People Learn*, pp. 38-40.

[60] *Ibid.*, p. 4. and pp. 45-48.

[61] Bransford et al., *How People Learn*, p. 10. For a different twist on this dealing with how people learn from and understand stories, see Roger C. Schank, *Tell Me a Story: A New Look at Real and Artificial Memory* (New York, NY: Charles Scribner's Sons, 1990), pp. 56-83.

suggests that a "one-size-fits-all" approach to learning may fail to accommodate this progressive self assessment and may not properly engage each individual learner's existing knowledge, since each learner will have a slightly different background.[62]

Bransford et al., highlight three key findings that research has revealed about learning:

> 1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom.
> 2. To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.
> 3. A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.[63]

Although these key findings appear to be directed toward children, the authors note that they apply to adult learning as well. They even use examples of how professional development programs for teachers often violate many of these principles![64]

There are several implications based on each of these principles for a program to transfer expertise-related knowledge between generations of intelligence analysts. First, since the novices who will be learning the knowledge will generally have different educational backgrounds and work experiences, the learning experience must be geared towards engaging them at their level and in terms they can understand. Second, the knowledge elicited from the experts must capture the factual knowledge, information on the contexts in which it applies, and a system for organizing and making connections within the knowledge. Third, information on

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[62] Bransford et al., *How People Learn*, p. 12.
[63] *Ibid.*, pp. 14-18.
[64] *Ibid.*, pp. 26-27.

the typical stumbling blocks and barriers to learning the knowledge must be discovered to help learners get through these difficulties. Fourth, the knowledge captured must include information learners can use to gauge their own understanding.

We have only touched on a few of the most important lessons from the science of learning and will rely on additional insights from this discipline in the next section. For now, it is time to consider some knowledge preservation projects that government organizations are using to help extract expertise-related knowledge from their aging workforces.

Knowledge Preservation Efforts. Several U.S. government organizations are pursuing knowledge preservation projects. Some projects have accumulated a considerable amount of experience while others are still on the drawing board. The discussion that follows is not based on a comprehensive survey of government knowledge preservation projects, but rather a brief discussion of a few projects that have valuable implications for the ONI case.

Some of the most mature government knowledge preservation projects are at the U.S. Department of Energy (DOE). These projects are part of the DOE's efforts to preserve the knowledge base needed to operate a downsized nuclear weapons complex.[65] Faced with a moratorium on nuclear testing and cessation of designing and building new nuclear weapons, DOE must find ways to ensure the integrity of the existing stockpile of nuclear weapons and preserve the knowledge and expertise required to resume nuclear weapons development and testing, should changing world events drive the nation back in this direction.

Since the early 1990s, DOE's major focus has been on science-based stewardship of the nuclear weapons stockpile. The vision is to use scientific understanding and expert judgment to

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[65] For a recent and concise overview of the problem facing DOE and some of the progress being made at Los Alamos National Laboratory see Evan Ratcliff, "Inside Nuke University," *Wired,* March 2002, 66-70.

predict, identify, and correct problems in the stockpile. Non-nuclear testing and computer simulation technologies are expected to play a significant role in this effort.[66] Knowledge preservation is a key part of the overall Stockpile Stewardship Program. The goal is to capture and preserve the accumulated knowledge of the nuclear weapons complex.

Elements of knowledge preservation at DOE include document archiving and knowledge capture activities. Document archiving activities range from cataloging and scanning documents for electronic access to analysis and reinterpretation of past nuclear and non-nuclear test data to help develop new computer simulation models. Knowledge capture activities consist of recording interviews with retiring or retired analysts. These activities fall under the Nuclear Weapons Information Project.[67] Since knowledge capture is one of the main thrusts of this study, the following discussion focuses on the interviewing of experts.

At DOE, interviews have been conducted with individuals and panels of experts with weapons knowledge. The objective has been to capture valuable knowledge that has not been documented in any other way. Some information that might have otherwise been documented was not committed to writing because of security concerns over its sensitive nature and because the frenetic pace of the weapons program in the 1950s and 1960s did not allow time for detailed documentation to be created.[68]

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[66] DOE Office of Inspector General, *The U.S. Department of Energy's Efforts to Preserve the Knowledge Base Needed to Operate a Downsized Nuclear Weapons Complex* (DOE/IG-0428, October, 1998) <http://www.ig.doe.gov/pdf/ig-0428.pdf> [May 13, 2002]

[67] *Preserving Nuclear Weapons Information*, Lawrence Livermore National Laboratory web page, <http://www.llnl.gov/str/Lowns.html> [April 27, 2002].

[68] Dan Stober, "Nuclear Secrets: Steal This!," *Bulletin of the Atomic Scientists* 55 (1999): 14-16.

Examples of the type of information recorded in these interviews include problems encountered in designing weapons, reasons for design choices, operational safety, and the art of weapons design and production.[69]

It is enlightening to compare the knowledge capture activities at several DOE sites. Table 1 summarizes these activities. The information dates from August 1998 and does not reflect the current status of these projects.

Table 1

Comparison of Knowledge Capture Activities at Several DOE Sites

Site	Sessions	Artifacts	Digital Video Archive?	Comments
Sandia	132 individual & panel discussions	> 870 video tapes	Yes	$4.5 million Estimated costs 60 more video tapes planned
Los Alamos	24 panel sessions	video tapes	No	No plans for digital video archive $400K estimated costs
Livermore	200 hours	video tapes	Yes	
Pantex	not specified	paper	No	Abandoned videotaping
Y-12	239 interviews	paper & electronic transcript	No	Effort completed in four years

SOURCE: DOE, *Efforts to Preserve the Knowledge Base*, (1998), pp. 4-5. and <http://www.bmpcoe.org/bestpractices/internal/oakri/oakri_88.html> [May 20, 2002].

[69] DOE, *Efforts to Preserve the Knowledge Base,* pp. 1-2.

The method and extent of recording interviews with experts varies across the DOE sites. Although videotaping interviews and panel discussions is a common practice at most of the sites, officials at Pantex abandoned videotaping in favor of documenting interviews on paper because they believed that "videotapes did not provide value-added information."[70] Pantex's experience with video highlights the importance of pre- and post-interview activities to ensure the knowledge captured is worth preserving, it is captured in a form that fosters learning and transfer, and it is suitably indexed for efficient search and retrieval. The Pantex view of video may have been more positive had they approached their video capture efforts from more knowledge- and learner-centered perspectives.

In all of these efforts, it is not clear to what extent these videos have been used by learners and what approaches, if any, have been used to structure the video content toward the needs of learners.

Two similarities come to mind when comparing DOE's knowledge preservation problem with that of ONI. First, both ONI and DOE share concerns over the security and access controls required for sensitive, compartmented information. ONI can benefit and learn from the development and testing experience at DOE. Work is progressing on a "pyramidal" need-to-know scheme where individuals at the top have access to most of the information while individuals lower on the pyramid are only authorized access to information in a particular domain or about a specific weapon system.[71]

Second, experts in both organizations have had to safeguard classified information resulting in a "disincentive to write or keep technical papers that would then become the author's

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[70] *Ibid.*, pp. 4-5.
[71] Stober, "Nuclear Secrets."

responsibility to keep secret" and both organizations maintained a breakneck pace to keep ahead of the Soviet Union during the Cold War.[72] For these reasons, experts at ONI may have not completely documented important knowledge.

One important difference between ONI and DOE's knowledge preservation problems is that DOE is concerned with trying to preserve design and test knowledge *in case* it is needed in the future as it shifts to science-based stewardship of the U.S. nuclear weapon stockpile while at ONI the need is for *uninterrupted* analytical capability. The emphasis at DOE is "downloading" essential information from expert's heads for future scientists. For ONI, downloading may be desirable, but the most important need is to get knowledge into new analysts' heads without experiencing any gaps in capability.

DOE's knowledge preservation projects offer three lessons. First, a well planned knowledge preservation program must take into consideration the needs of the learners that will use the knowledge captured on video. These consideration should shape the content of the video sessions. Second, ONI can learn from and take advantage of the security-related experience with technology gained in DOE's knowledge preservation projects. Third, ONI must emphasize the direct transfer of knowledge between analysts' heads over "downloading" because of the need to maintain uninterrupted intelligence analytical capability.

Officials at the Naval Air Systems Command (NAVAIR) are also concerned about knowledge preservation. They have plans for a pilot project and have videotaped interviews with one individual. They captured three hours of video in an attempt to elicit Test and Evaluation (T&E) knowledge from a retiring manager at NAVAIR. Although the intent was to capture technical knowledge, the project's knowledge workers were disappointed with the

[72] Ratliff, "Inside Nuke University."

content they captured. Instead of technical details about T&E projects, the video revolved primarily around management concerns and issues. The expert they interviewed had worked in T&E in the past, but spent the last several years as a senior executive.[73]

Although NAVAIR's knowledge preservation efforts are still in their infancy, the results of their experiment with videotaping offer at least two lessons. First, it is not clear the right person was identified for interviews to capture T&E technical knowledge. Also, the reason T&E was selected over other air warfare domains is not clear. An obvious lesson from this experience is to find the right experts and have an end use for the knowledge in mind before videotaping interviews. Second, from a discussion with a knowledge worker familiar with the videotaping sessions, it is clear that the interviewers were not trained in conducting interviews and did not use interview techniques designed to elicit expert knowledge.[74] The lesson here is that interviewers can benefit from gaining some experience and training in interview techniques.

Finally, it is not a good idea to try and draw too much from or be too critical of an effort that was clearly an experiment. Such experimentation is a critical element of successful knowledge management programs (remember Fahey and Prusak's deadly sin number nine: "Failing to recognize the importance of experimentation").

Summary. In this section, some lessons from knowledge management, the science of learning, and government knowledge preservation projects were discussed. Knowledge management is a valuable source of ideas because the theory of organizational knowledge creation and resulting guidance has been synthesized from hundreds of projects. From the theory of organizational knowledge creation, the central role that tacit knowledge conversion and

[73] Sherry L. Mitchell, telephone conversation with author, 30 April 2002.
[74] Such techniques include methodologies for cognitive task analysis discussed in the next section.

human interaction play in creating new products and services can also be seen to apply in the transfer of knowledge between people. The fundamentals are the same—people embedded in organizations wrestling with tacit and explicit knowledge. The knowledge management project guidelines and pitfalls provide some "rules-of-thumb" to consider when constructing a model of knowledge preservation.

Results from the science of learning indicate that knowledge capture activities are only one part of the knowledge transfer process. Unless the learner's needs are used to guide the knowledge capture activities, important information about the applicable contexts, the best ways to organize the knowledge to solve problems, and the cues learners can use to monitor the progress of their own learning may be missed. Other lessons that can enhance learning and knowledge transfer include the need to engage a learner's initial understanding and preconceptions and the need to identify common barriers and obstacles to learning. Lessons from government knowledge preservation projects highlight the value of planning and preparation to identify the right sources of knowledge and establish priorities for the knowledge to be captured. Lessons from DOE's experience recording hundreds of interviews and using a networked digital video archive with security access controls can be used by ONI to overcome similar challenges. The video experiment at NAVAIR highlights the importance of identifying the right experts, identifying an end use for the knowledge captured, and using interview techniques to guide the discussion and probe critical areas to help elicit knowledge.

This brief background survey of industry, science, and government suggests the potential benefits from a framework or model around which a knowledge preservation program can be constructed. In the next section a knowledge preservation model is developed and presented.

SECTION V

KNOWLEDGE PRESERVATION MODEL

Making things look easy is hard. Clarity requires depth.
-- Tor Nørretranders[75]

Introduction. This section explains a proposed knowledge preservation model for organizations faced with experts who have retired or will retire in the near future. This model draws on ideas from knowledge management and the science of learning that were presented in the previous section. Unlike conventional knowledge preservation approaches which focus almost exclusively on knowledge capture activities and on the archiving of data and information, the model presented here focuses on the end-to-end transfer of knowledge from the heads of retiring experts to the heads of their replacements.

This section begins by constructing a simplified model of end-to-end knowledge transfer to serve as the foundation for an overall knowledge preservation model. This simplified model and the rationale behind it will then be used to infer some implications for knowledge preservation and build a case for adopting a story-centered approach to learning. Next a three-pronged model for knowledge preservation is described. Finally, highlights are summarized and the stage is set for considering how to put the model into action at ONI in the next section.

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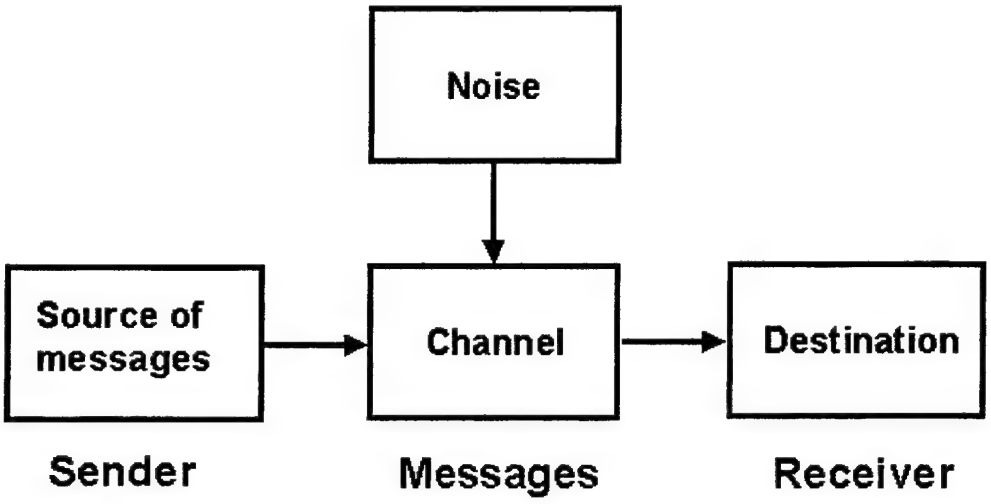
[75] Tor Nørretranders, *The User Illusion: Cutting Consciousness Down to Size*, trans. Jonathan Sydenham (New York, NY: Penguin Putnam, Inc., 1998), p. 79.

A Simplified Model of Knowledge Transfer. One way to view knowledge transfer is to think in terms of a cybernetic communication model.[76] This model consists of a sender that acts as a source to encode and send messages over a communications channel to a receiver which decodes and receives the messages. Noise, a "general term for anything that tends to produce errors in transmission," can also degrade performance as it is added to the messages.[77] These model elements and their relationships are depicted in figure 4. This model was used to

Figure 4

Cybernetic Communication Model



SOURCE: Adapted from Ash (1965), p. 1.

formulate information theory and has led to the development of today's communication systems and other products including compact disk players. Although a powerful model, its use here is as

[76] Claude Shannon and Norbert Weiner developed much of the theory that led to the popularity of this model. The ideas behind its use here come from Robert B. Ash, *Information Theory* (New York, NY: Dover Publications, Inc., 1965) and W. Ross Ashby, *An Introduction to Cybernetics* (London, UK: Chapman & Hall, Ltd., 1957)

[77] Ash, *Information Theory*, p. 1.

a point of departure to develop a more comprehensive model of knowledge transfer between people.[78]

The cybernetic communication model is very general in the sense that the rules governing properties like the channel capacity hold for many different circumstances.[79] For example, the sender could be a satellite ground station sending messages over a channel consisting of the path from the ground station to a geosynchronous satellite back down to a receiver on a ship at sea. Or the sender could be musician in a recording studio whose song is recorded and then transmitted through the channel consisting of a compact disk which is in turn played by a music fan who serves as the receiver.

So it would seem logical to try to extend this model to the case of knowledge transfer where the sender is a retiring expert transmitting knowledge in the form of messages to a someone designated to learn the retiring expert's craft. Here the channel could consist of direct verbal conversations, video tape, documents, procedures, test results, and other suitable media and artifacts for transmitting knowledge. For this model to work the receiver must understand how to decode the messages and it must understand what the symbols mean. For a satellite

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[78] A more comprehensive model has a better "relation-structure" to the process it models and hence does a better job of explanation. Johnson-Laird uses an example of how a person's mental model of a television set might be limited to a box that displays moving pictures with sound. This level of understanding is adequate for many people, but a television repairman would have a much richer mental model of a television set that includes an electron beam being electromagnetically steered in a raster pattern to form the images on the screen. This level of detail in a model would serve to explain why the picture is distorted when an external magnet is placed near the set. One could also have an even more detailed model that included perhaps the quantum mechanical effects, but this extra detail would not add significantly to the explanatory function of the repairman's model. See P. N. Johnson-Laird, *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness* (Cambridge, MA: Harvard University Press, 1983), pp. 3-4. quoting Kenneth Craik, *The Nature of Explanation* (Cambridge, UK: Cambridge University Press, 1943).

[79] Ashby, *An Introduction to Cybernetics*, p. 155.

communication system, the engineers who design the system understand this and build their receivers accordingly. For compact disks, music lovers just listen to music over their headphones and enjoy the emotional states aroused. However, messages encoded with expertise-related knowledge are not ordinary messages, and a learner does not automatically know how to understand and decode knowledge from a retiring expert. Some adjustments are needed to make a more useful model.

Part of the difficulty in applying the cybernetic communication model to knowledge transfer stems from the fact that the "information content" in information theory is independent of meaning. The information content of a message is a measure of the uncertainty in the message based on a calculation involving the number of possible states it could assume. By this measure, one message heavily ladened with meaning could have the same information content as another message that is pure nonsense.[80]

How does one then account for meaning in a message? One way is through the ease of its predictability. Consider a disordered message, one composed entirely of random noise. The exact value of such a message at any instant is uncertain. However, such a message is still fairly predictable. In many cases, it can be completely described by a few statistical parameters such as the values of its mean and standard deviation. Now consider an ordered message, one composed of a fixed, repeating pattern. This message can be easily predicted once one knows the pattern. This implies that the notion of meaning or value in a message must somehow be tied up in something that lies between order and disorder.

> The value of a message thus appears to reside not in its information (its absolutely unpredictable parts), nor in its obvious redundancy (verbatim repetitions, unequal digit frequencies), but rather in what might be called

[80] Nørretranders, *The User Illusion,* p. 99.

> its buried redundancy—parts predictable only with great difficulty. In other words, the value of a message is the amount of mathematical or other work plausibly done by its originator, which the receiver is saved from having to repeat[81]

Charles Bennett, a physicist and pioneer in the study of complexity, called this plausible amount of work in a message its "logical depth" and associated it with a measure of complexity. "Complexity, in this sense, is a measure of how hard it is to put something together starting from elementary pieces."[82]

The key idea is to make the connection that the meaning or value of a message lies in something that is "missing" from the physical message. Nørretranders makes the following connection between logical depth and missing information:

> Logical depth is a measure of the process that leads to a certain amount of information, rather than the amount of information that is produced and is transmitted. Complexity or meaning is a measure of the production process rather than the product, the work time rather than the work result. The information discarded rather than the information remaining[83]

It is not the face value of the information that defines its depth, but how difficult the information was to generate. For example, "$1.59 per pound" does not contain much information by itself. However, if I am shopping in the supermarket and I need to find the best buy between two different brands in three package sizes, I need to calculate the per unit price for each option. These calculations take time and effort. Information is discarded along the way. The price of a package, the number of ounces, the conversion factor from ounces to pounds are all no longer needed to make the comparison once you have the answer. When the grocer

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[81] Charles Bennett, "Logical Depth and Physical Complexity," quoted in Nørretranders, *The User Illusion,* pp. 77-78.
[82] Heinz R. Pagels, *The Dreams of Reason: The Computer and the Rise of the Sciences of Complexity* (New York, NY: Simon & Schuster, Inc., 1988), p. 67.
[83] Nørretranders, *The User Illusion,* p. 79.

provides the per unit prices on the shelf next to each item, he has saved me a certain amount of computational time.[84]

The concept of logical depth is not restricted to supermarket aisles. One can think of logical depth in terms of human conversations. Nørretranders illustrates this point with an example of the communication between the French novelist Victor Hugo and his publisher. While vacationing after writing the novel *Les Misérables*, Hugo became curious about how well his new book was selling. He cabled his publisher with a message consisting of a single question mark: "?" His publisher replied with a single exclamation point: "!" Hugo's book was doing very well indeed.[85] This exchange would be meaningless without the shared context between Hugo and his publisher. With their shared context, they are able to discard an extreme amount of information.

> ... our words contain more than can be measured in bits. Because it is not what we say to each other every day that establishes all the meaning and beauty and truth our everyday conversations contain; it is everything we think before we speak ... there must be something else that really counts: the real source of beauty, truth, and wisdom. The ironic thing is that this "else" can be described as the information we have got rid of: *exformation*. Meaning is information that has been discarded: information that is no longer present and no longer needs to be.[86]

Nørretranders compares the relationship between information and meaning to the relationship between money and wealth. The real value of money lies in getting rid of it. That is what provides the substance of real wealth. It is not having a lot of money per se, it is having the possessions and trappings that money can buy.[87]

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[84] *Ibid.*, p. 79.
[85] *Ibid.*, p. 91.
[86] *Ibid.*, p. 98.
[87] *Ibid.*, p. 98.

The information in a message that gets explicitly discarded is called *exformation*. In one sense the value and the worth of a message—its meaning—lies not in its information but its exformation. In other words, the information that was discarded along the way.

If exformation is explicitly discarded information, then exactly what does a word mean? For example, what do we know when we know what a *dog* is? This is something that most people take for granted. However, when one starts to really think about what seems a simple concept, for instance, defining a word like "dog," it becomes clear that how the mind works is actually quite complicated. For example, one could define a dog as an animal having four legs, fur, a tail, and the ability to bark. The problem is that for every defining characteristic one can name, there is an exception. Consider a dog that has lost a leg or lacks a tail. It is still a dog and one can easily recognize such an animal as a dog. Ludwig Wittgenstein, a twentieth century philosopher, introduced the concept of family resemblance to explain how people get around these difficulties in everyday practice. Just as one can recognize the members of a human family by similarities in properties such as eye color, height, expression, and temperament, so can one recognize a dog by its similar properties of "dogness."[88]

The point of this digression into the meaning of a word is that there is a lot of processing going on behind the scenes, of which people are unaware, on both the transmit and receive side of a conversion when they use a common word like "dog." Communicating with these common words is possible because most people have developed an understanding of what these words mean. What about less common words, concepts, and ideas that a person on the receiving end of a conversation is less likely to be familiar with? This is where the notion of logical depth and

[88] For an in-depth discussion of family resemblance see Johnson-Laird, *Mental Models*, pp. 187-191 and Reisberg, *Cognition*, p. 273.

exformation can be used to modify the cybernetic communication model by incorporating some relation-structure to account for perception and mental processing.

Consider that your five senses and the mental processing associated with them consume about eleven million bits per second in information terms, while language and the consciousness that process it occupy only about forty bits per second. These numbers, although approximate, are not speculation; they have been substantiated through many scientific experiments. A vast amount of information is discarded when we go from experiencing life in person to explaining it in words.[89]

Humans also must discard a lot of information when they tell a story. Mental imagery, sensations, and intuition all peel off in the process of thinking that ends in the spoken or written word. "We can know more than we can tell," said Polanyi.[90]

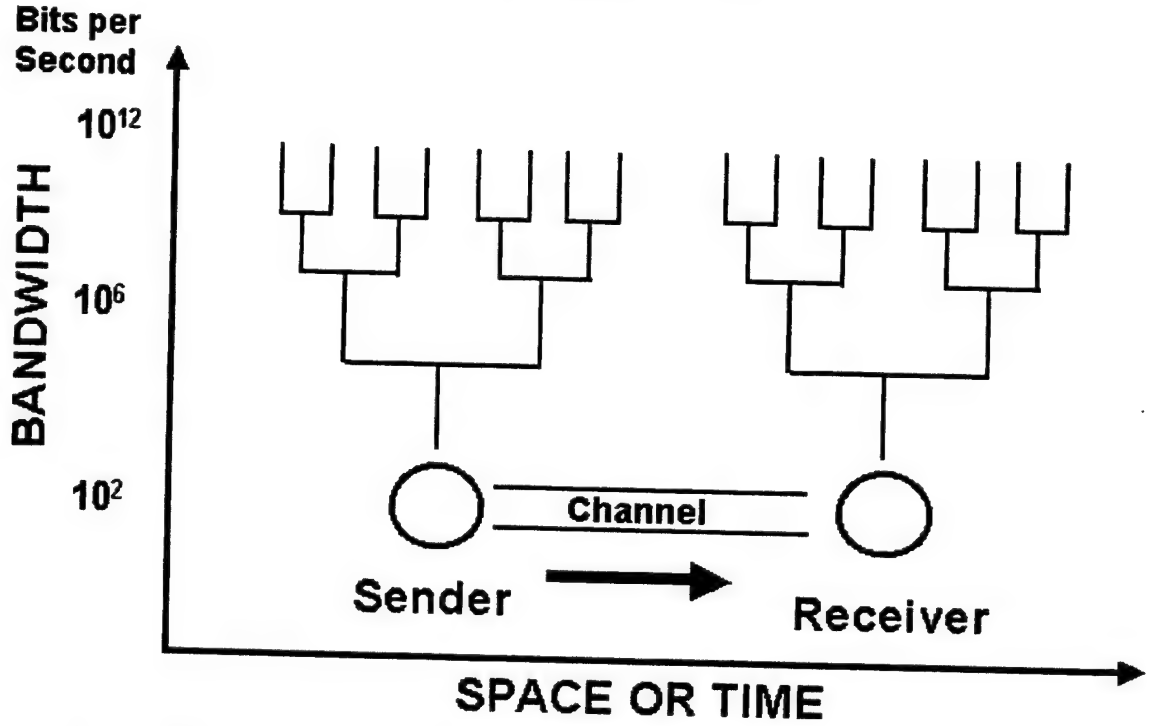
[89] Nørretranders, *The User Illusion,* p. 126.
[90] Polanyi, *The Tacit Dimension*, p. 4.

These ideas can be used to adjust the cybernetic communication model of figure 4. Both the sender and receiver are replaced by what Tor Nørretranders calls "the tree of talking."[91] This is shown conceptually in figure 5. Once again, imagine the sender to be the retiring expert and the receiver to be the aspiring learner. Here is how Nørretranders describes the process:

> The movement proceeds from the left-hand treetop down to its root, through the forest floor and up the right-hand tree. On the left, a lot of information is compressed via the discarding of information, the production of exformation. Thoughts are composed into words. We can call this *incitation*. On the right, the limited information in the words is received. This is unfurled into more information. We can call this second process *excitation*.[92]

Figure 5

Tree of Talking Communication Model



SOURCE: Adapted from Nørretranders (1998), p. 146.

[91] Nørretranders, *The User Illusion,* pp. 91-123.
[92] *Ibid.*, pp. 110-11.

Nørretranders points out that the model applies beyond language to music, for example, which has its own tree. He also cites cognitive neuroscience and brain studies which provide evidence that more than guesswork lies behind the notion of these trees.[93]

Now we have a conceptual model of knowledge transfer from which to build a model of knowledge preservation that accommodates some of the lessons from the previous section, including the need to engage learners' previous knowledge and the need to provide context for information.

Implications for Knowledge Preservation. The first inference to draw from the tree of talking communication model is the need for an expert to throw away information in order to communicate knowledge to a learner. The expert needs to produce exformation. The information that is discarded needs to be carefully selected so that the remaining message conveys the essence of the ideas behind the knowledge and, at the same time, refers to information which can be easily excited in the mind of a learner. This occurs naturally, for example, when someone composes a story to tell another person. As someone relates the gist of a story, he necessarily takes an intentional stance to consciously elaborate on some details while glossing over others.[94] This idea relates to some lessons from the science of learning. Since it is the context of the factual knowledge, the fluent retrieval of pertinent facts, and how an expert's knowledge is organized that most influence the difference in competency between novices and

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[93] *Ibid.*, pp. 111-20.

[94] For a description of how the gist of a story is transformed into a realization in language see Schank, *Tell Me a Story*, p. 25. For more on the intentional stance and its relationship to meaning see Daniel C. Dennett, *The Intentional Stance* (Cambridge, MA: The MIT Press, 1987), p. 17, p. 132.

experts, it is information relevant to these details that must be conveyed while other information is explicitly discarded.[95]

The second inference to draw from the tree of talking model is the need to engage a learner's existing knowledge. Learning is not effective unless the expert's message resonates with and excites relevant trees in learner's mind.

> A good communicator does not think only of himself; he also thinks about what the receiver has in his head. It is not enough for the explicitness of the information to refer to some information in the sender's head if that information does not somehow lead to the correct associations by the receiver.[96]

This idea relates back to the lessons from the science of learning that new knowledge must be constructed from and combined with existing knowledge. This helps to explain why redundancy is one of Nonaka and Takeuchi's enabling conditions for organizational knowledge creation. Redundancy provides a common vocabulary and mental models for people to use in relating to one another.

The third inference is the need for rich "high bandwidth" interaction between people. One-on-one interaction between an expert and a learner is the most direct form of this. Video teleconferencing is another form high bandwidth interaction, although it is less rich than one-on-one interaction. Recorded video is another high bandwidth form of communication, although it is hardly interactive. An advantage of one-on-one interaction is that it provides an opportunity for feedback from the learner that the expert can use to make adjustments in his message's exformation and thereby better convey knowledge. Also, one-on-one interaction need not be confined to the low bandwidth of speech and writing but can also take place by watching the expert at work and socially by "getting to know one another." These higher bandwidth forms of

[95] Refer to the subsection on the science of learning in Section IV.
[96] Nørretranders, *The User Illusion,* p. 93.

interaction occur further up the tree and can add substantially to the quality of learning that takes place.

The need for high bandwidth relates back to Nonaka and Takeuchi's theory of knowledge creation. Their theory revolves around the mobilization and conversion of tacit knowledge. In both the conversion of tacit to explicit knowledge through externalization and the conversion of tacit knowledge between individuals through socialization, information is discarded and exformation is produced.[97]

In terms of the tree of talking model, interaction higher up the tree can result in shared experience and a greater chance of achieving shared meaning. This idea relates back to the lessons from knowledge management in that socialization (the tacit-to-tacit knowledge conversion process) makes use of high bandwidth connections as learners "share experiences" or engage their five senses as they "learn by doing." In internalization, the explicit-to-tacit knowledge conversion process also makes use of high bandwidth. This occurs in the mind of the learner as he "assimilates" the explicit knowledge into mental "terms of his own" or tacit knowledge. Lessons from the science of learning also relate to the advantages of a high bandwidth learning channel. First, multiple channels and high bandwidth connections provide more opportunities for engaging existing knowledge in the learner's mind. Second, they can also help with one's ability to self-assess understanding or metacognition by providing a learner with a "feel" for the subject. Another high bandwidth way to achieve this is through the use of computer simulations and experimentation. For example, although Microsoft Flight Simulator™ is not as realistic a flying experience as actually going up in an airplane behind the controls, it is a much richer experience flying the simulator than just reading about it.

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[97] See figures 2 and 3 in Section IV for a visual representation of these processes.

Having constructed a simplified model of knowledge transfer and used it along with some of the lessons from the previous section to draw inferences for a knowledge preservation model, it is time examine exactly what form an expert's messages should take. It is time to make a case for story-centered learning.

A Case for Story-Centered Learning.[98] The case for using story-centered learning in knowledge transfer starts with establishing a connection between stories and knowledge. Next, the discussion turns to Schank's three models for how intelligence and stories are related. This is followed by looking at the role reminding plays in conversation and stories. This leads to a discussion of storytelling as understanding and how stories can be used to get one's point across. The role "indexing" plays in our ability to recall stories and why they are so easy to remember is discussed as a major advantage for learners and information systems alike. Next the link between sensemaking and stories is discussed. Finally, stories are depicted as a way to capture a slice of an expert's knowledge and experience in a digestible easy to remember form.

To understand the connection between knowledge and stories consider that a person's knowledge of the world is bound up in the set of experiences he or she has had. Not all of a person's memories are stories, but the interesting ones and the ones a person has learned something from are stories. For example, eating a bowl of cereal for breakfast on any given day is pretty much like any other bowl of cereal. It is not memorable. However, if there is a car crash nearby one day while eating breakfast, the bowl of cereal becomes memorable because it is

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[98] There is an ample body of literature on the use of stories to convey knowledge. Many of the ideas presented here come from Schank, *Tell Me a Story.* For the use of stories to transfer tacit knowledge in organizational settings see Walter Swap et al., "Transferring Tacit Knowledge Assets: Mentoring and Storytelling in the Workplace," *Journal of Management Information Systems*, Summer 2001. For the power of stories for eliciting knowledge from experts see Gary Klein, *Sources of Power: How People Make Decisions* (Cambridge, MA: The MIT Press, 1998), pp. 177-96.

now part of a story. Likewise the events a person can recall to tell others is limited to the stories at a person's disposal to tell. "In other words, all we have are experiences, but all we can effectively tell others are stories."[99]

Schank uses three models to explain how stories and intelligence are related. The first model is the *librarian*. If a library patron asks for help finding information on a topic, the librarian may refer him to a particular section of the library or the librarian may suggest a particular book that seems appropriate but the librarian has not actually read, or the librarian may be reminded of having read exactly the book the patron is seeking. Any of these three possible responses from a human librarian to a request for help would be seem intelligent. In this model, a librarian's intelligence is "in translating what we say into the system of labels by which all the books he knows about have been encoded."[100] Here the appearance of intelligence is bound up in *being able to find the right thing*.

The second model is the *grandfather*. Many grandfathers tell the same stories over and over. Occasionally, a new and interesting story is told which no one remembers hearing and that the grandfather tells with enthusiasm. A question Schank poses is: is such a grandfather wise? He maintains the answer has to do with knowing the difference between intelligence and wisdom.

> We are willing to ascribe wisdom to those who are not so quick to draw conclusions but rather who see many sides to a problem and attempt to draw reasonable analogies. Or to put this another way, wisdom is often ascribed to those who can tell just the right story at the right moment and who often have a large number of stories to tell. Furthermore these stories rarely draw all the conclusions for the hearer. Rather, they present information, often leaving out the final conclusions.[101]

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[99] Schank, *Tell Me a Story*, p. 12.
[100] *Ibid.*, p. 14.
[101] *Ibid.*, p. 14.

Here the appearance of intelligence depends on *what is said rather than what is actually understood.* Schank points out that a computer with a vast repertoire of stories that carefully selects the right ones at the right time can appear wise although the computer may have no actual understanding of the stories it tells.[102]

The third model is the *logician.* The idea here is that every problem *can be broken down* into a form that can be decided by some form of logic. However, people are not set up to think like this; people like to tell and hear stories because stories provide context.

> When a decision-making heuristic, or rule of thumb, is presented to us without a context, we cannot decide the validity of the rule we have heard, nor do we know where to store this rule in our memories. Thus, what we are presented is both difficult to evaluate and difficult to remember, making it virtually useless. People who fail to couch what they have to say in memorable stories will have their rules fall on deaf ears despite their best intentions and despite the best intentions of their listeners. A good teacher is not one who explains things correctly but one who couches explanations in a memorable (i.e., an interesting) format.[103]

What emerges from this discussion of knowledge, stories, and intelligence can be summed up in the following quote: "Knowledge, then, is experience and stories, and intelligence is the apt use of experience and the creation and telling of stories."[104] Perhaps what ONI needs most, are grandfathers, but with the skills of both librarians and logicians.

Stories can also be very effective at getting a point across. This helps to explain why techniques such as the use of parables in the Bible and ancient myths have had such a long history. Part of this effectiveness stems from the idea that just being told a rule does not provide

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[102] *Ibid.*, p. 15.
[103] *Ibid.*, p. 15.
[104] *Ibid.*, p. 16.

a context nor produce the visual imagery and other perceptual associations that go along with the remindings that are part of understanding a story. "Stories illustrate points better than simply stating the points themselves because, if the story is good enough, you usually don't have to state your point at all; the hearer thinks about what you have said and figures out the point independently. The more work the hearer does, the more he or she will get out of your story."[105]

Another feature of stories and one reason they are easy to recall is the many ways they can be indexed in memory or a knowledge retrieval system. A judicious set of well indexed stories is one way to capture some of an expert's highest value knowledge in a form that fosters learning and retrieval.

People find the stories they wish to tell though *indexing*. Indices serve as labels that aid in the storage and retrieval of stories. These labels provide connections. Reisberg points out that connections are how one memory triggers another, and this is how people understand the pieces of a story, by connecting them with pieces of stories they already are familiar with.[106] Indices can be described in terms of conceptual actions that relate to events in a story. Examples include *scripts*, *plans*, *goals*, and *themes*.[107] These indices are particularly well suited to label expertise-related knowledge. Schank describes how an expert in military history was found to access his knowledge using this type of index-like scheme. Schank proposes that an expert "is someone who has a great many stories to tell in one particular area of knowledge and who has those stories indexed well enough to find the right one at the right time."[108]

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[105] *Ibid.*, pp. 11-12.
[106] Reisberg, *Cognition*, p. 153.
[107] Schank, *Tell Me a Story*, pp. 84-114.
[108] *Ibid.*, p. 109.

This implies that an indexing scheme such as that shown below could be used to elicit knowledge in the form of stories from a retiring expert and later be used as an index to retrieve a related video clip of the expert telling the story. An example index might be:

Theme:	Approaches to S&T intelligence analysis
Goal:	Understand enemy weapon system
Plan:	Invent a dynamic scenario that pits one weapon system against another and analyze each weapon system's performance
Result:	Analyst gets a richer understanding than static numbers can provide
Lesson:	One learns more from a dynamic situations than from static situations

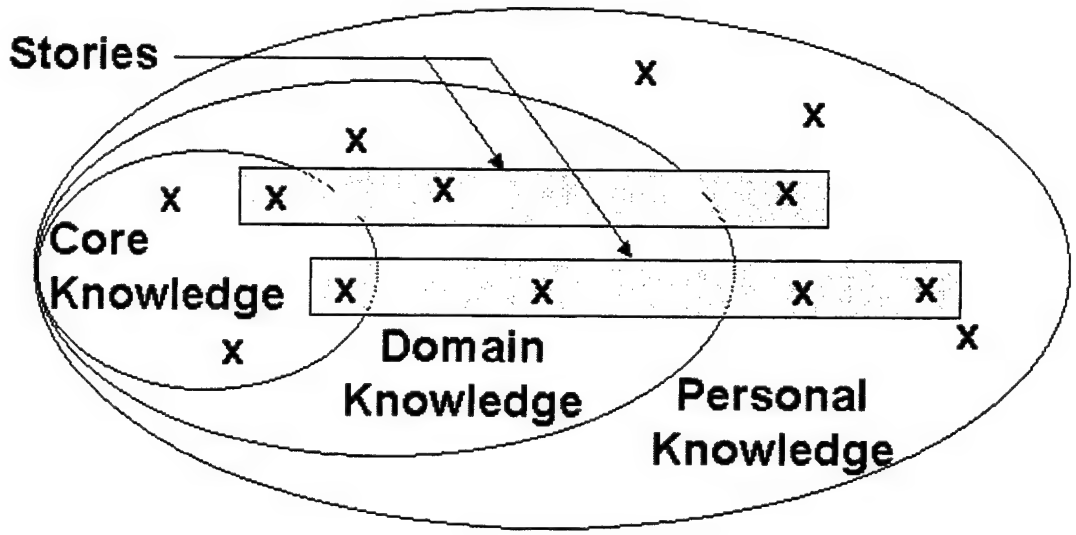
The knowledge in the preceding example can be indexed and captured in a relevant story as an example. Because stories are related to and useful for understanding, they are also useful for sensemaking (making sense out of one's situation and environment). Stories can be used to organize information to check for consistency and plausibility when trying to sort things out. Can one concoct a story to account for the facts? If so, such a story can possibly have great explanatory power.[109]

[109] Michael S. McBeth, "Approaches to Enhance Sensemaking in Intelligence Analysis." Unpublished Study Report, Naval War College, Newport, RI, 14 February 2002.

Stories can capture a slice of an expert's knowledge in a context that is easier for learners to digest and recall than disassociated facts and rules. Figure 6 is a conceptual drawing that shows an expert's knowledge represented as three encompassing ellipses. Core knowledge represents all of the underlying basics. Domain knowledge represents domain specific

Figure 6

Stories Capture a Slice of an Expert's Knowledge



knowledge. An example is the knowledge about how submarines are designed, built, tested, and operated. Personal knowledge represents knowledge specific to an individual that usually relates to past experiences or episodes. An example is a specific bit of knowledge captured in a project folder an analyst used to solve a problem back in 1995.

If the "Xs" in the figure represent particular nuggets of information that may be relevant in the future, stories can be captured that slice across the expert's knowledge to encapsulate certain nuggets in a context. These nuggets can then serve as one set of indices for retrieval from a learner's memory or from a searchable knowledge archive.

Since stories represent slices of knowledge, this picture indicates that one would not want to depend on stories alone to build a learner's core knowledge (especially a deep knowledge of the factual contents of a subject). This basic level of learning and understanding is usually mastered through formal education, mentoring, organized training programs, and self-study.[110] Fortunately, in the case of transferring knowledge from retiring experts to their replacements, the replacements usually have already acquired the necessary core knowledge in the subject area under study. However, for domain and personal knowledge, stories may be the most effective way to transfer knowledge in a context.

Lessons about the nature of expertise from the science of learning in the last section identified the importance of having a context for facts and ideas that make up knowledge. Stories and narrative provide this context. Stories are a natural way people share knowledge and experiences. Stories are more memorable than a list of disassociated facts and, therefore, more likely to acted upon. Stories also tend to be elaborated by vivid images in a learner's mind drawn from past experiences. In this way, stories "tap into" a learner's tree of talking.

Having introduced a simplified model for knowledge transfer and made a case for story-centered learning, it remains to apply these concepts within the framework of an organization. What processes must be in place to efficiently transfer knowledge within an organization? Here the focus changes from considering a retiring expert as a sender and a learner as a receiver to considering the context of the entire organization's workforce. Next the discussion turns to the processes that make purposeful knowledge preservation occur broadly in an organization.

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[110] Swap, "Transferring Tacit Knowledge Assets."

Three Main Processes of Knowledge Preservation. Romhardt identified three main processes for organizational knowledge preservation; *selection*, *storage*, and *actualization*. Figure 7 shows these processes. Not all knowledge is worth preserving. Some knowledge is outdated. Still more knowledge is buried within a sea of project reports, meeting minutes, and working files too numerous to keep track of. The unexpected departure of a worker can leave many aspects of important projects poorly documented. For these reasons, Romhardt points out the need to develop selection rules to aid in determining what knowledge to preserve. The goal is to transfer valuable data, information, and skills into "organizational systems" which can be used by the whole organization. One way to make selection rules work is to assign clear responsibilities for the analysis and selection of knowledge to be preserved. Romhardt points out that every organization has "centers of competence" from which to assign a manager or team with the expertise to decide which knowledge is worth preserving. Just as information must be

Figure 7

Three Main Knowledge Preservation Processes

SOURCE: Adapted from Romhardt (1997), Fig. 1.1, p. 3.

discarded in the tree of talking communication model for an expert to communicate his knowledge, a similar process must take place at the organizational level as knowledge, in the form of single contributions and documents, must be condensed into central documents. This occurs, for example, when analyses and lessons learned on thirteen missile tests are summarized into one document. Users are not forced to read and interpret all the individual missile test analyses to learn the important aspects of the available knowledge.[111]

Romhardt categorizes the *storage* of organizational knowledge in three forms: *individual*, *collective*, and *electronic storage*. Knowledge stored in the heads of individuals is where it is most useful, but also the most volatile. Retention incentives are one way to keep valuable employees with the organization and preserve individual knowledge. However, retention incentives generally do not apply to retiring workers. Flexible retirement and part-time employment are other options to retain access to valuable employees and their knowledge. When these options are not practical, steps can be taken to capture and store knowledge. Romhardt notes that structured exit-interviews conducted by trained experts can be an effective way to capture critical knowledge. He uses Sandia National Laboratory's videotaping program as a positive example.[112] Similar story-based interviews with retiring analysts are part of the knowledge preservation model developed in this section.

Knowledge can also be stored in a *collective* entity such as a group. Here limitations in the ability of a single individual to recall information can be improved by other members of a team or group. For many fast-moving project teams, the only practical way to capture central

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[111] Kai Romhardt, "Processes of Knowledge Preservation: Away from a Technology Dominated Approach," <http://www.dfki.uni-kl.de/~aabecker/Freiberg/Final/Romhardt/romhardt.html> [April, 27, 2002].
[112] *Ibid.*

project status information is in the form of meeting minutes. Romhardt notes that some Japanese companies emphasize the importance of recording good meeting minutes and provide special training for moderators. Shared language, where words and terms take on a special meaning within a group because of shared experience, are also another form of collective storage.

Advances in computer technology are making it possible to store vast amounts of information in digital form at reasonable costs. Here the guidance from the previous section on having some but not too much structure applies. Some degree of structure allows knowledge to be found efficiently. Some flexibility in structure allows the system to accommodate knowledge that is difficult to categorize in precise terms. Other important concepts for *electronic storage* include using a controlled vocabulary and indexing schemes which are important to allow efficient access to knowledge and help prevent valuable knowledge from being filed in the wrong places and potentially becoming lost.

Knowledge must be *actualized* or put to use to realize the benefits of knowledge preservation. The knowledge being preserved needs to be translated and applied in the daily activities of workers. Otherwise, knowledge fades over time and can be lost. The major problems Romhardt cites here are trust and access. Users must have confidence in the accuracy and timeliness of knowledge. A strategy here is to assign responsibility for certifying accuracy to the centers of competency experts mentioned above.[113] Having briefly defined three main processes for knowledge preservation, it is time to construct a model for knowledge preservation that rests on the foundations that have been laid.

A Three-Pronged Model for Knowledge Preservation. To understand how the principles discussed up to this point can be harnessed to construct a model for knowledge preservation,

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[113] *Ibid.*

consider how Christensen describes an analogy dealing with the development of heavier-than-air manned flight:

> ... the ancients who attempted to fly by strapping feathered wings to their arms and flapping with all their might as they leapt from high places invariably failed. Despite their dreams and hard work, they were fighting against some very powerful forces of nature. No one could be strong enough to win this fight. Flight became possible only after people came to understand the relevant natural laws and principles that defined how the world worked: the law of gravity, Bernoulli's principle, and the concepts of lift, drag, and resistance. When people then designed flying systems that recognized or harnessed the power of these laws and principles, rather than fighting them, they were finally able to fly to heights and distances that were previously unimaginable.[114]

Transferring knowledge between people has its own set of relevant natural laws and principles. Two principles that can be harnessed to design knowledge preservation systems are *one-on-one human interaction* and *high bandwidth communications*.

The advantages of one-on-one human interaction include the opportunity for feedback between the retiring expert and the learner, opportunities for tacit knowledge transfer through socialization and "getting to know one another," and interaction at levels higher up the tree of talking. High bandwidth transfer comes automatically with one-on-one human interaction. If you cannot have one-on-one human interaction, it is still possible to achieve relatively high bandwidth transfer using video or other rich media. With a desire for human interaction and high bandwidth in mind, the goal for a knowledge preservation model is to maximize the use of these two features.

From this perspective, the constraining factor becomes the amount of time a retiring expert has to interact with learners. It takes time to learn from an expert, in some cases, many years. Many sources point to traditional mentoring as the best way to transfer expertise-related

[114] Clayton M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (Boston, MA: Harvard Business School Press, 1997), pp. xviii-xix.

knowledge from an expert to a learner.[115] This is not too surprising since mentoring consists primarily of one-on-one human interaction. The first step in constructing a knowledge preservation model is to establish a lower bound on how long it takes to establish a productive traditional mentoring relationship. One can call this the "ample time available" case. That leaves two other cases: one case where the retiring expert lacks enough time for traditional mentoring, but has some time available for one-on-one human interaction, the "some time available" case; and a final case where the retiring expert has little or no time for one-on-one human interaction, the "limited time available" case.

Ample Time Available Case. Some lower bounds on the amount of time required for a traditional mentoring relationship can be estimated in the following way. First, consider that it takes time to get to know someone at work. It takes time to understand a person's situation and style of approaching problems. It takes time to establish a sense of trust and to figure out the boundaries. Perhaps this can be accomplished in as little as six months, but for the purposes of argument assume this process takes one year. Second, after getting to know someone, it takes more time to work on enough substantive projects to get exposure to the variety of problems needed to get the most from an expert-guided learning experience. Assume this takes an additional two to three years on the job. That means it takes three to four years to make traditional mentoring a viable option. Can meaningful mentoring take place in less time? Perhaps, but people still need to get to know each other and they need time to work on a variety of projects. This line of reasoning and the research on mentoring suggests that the minimum time necessary for a traditional mentoring approach is *three years*.

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[115] See Swap et al., "Transferring Tacit Knowledge Assets" for a discussion of mentoring and a review of the relevant literature.

Some Time Available Case. If it takes at least three years to make traditional mentoring viable, what can be done if less time is available for one-on-one interaction? Most options will likely result in a tradeoff between depth and breadth of learning. One idea that has been proposed is to have a learner build a case study based on a significant experience or project from a retiring expert's career and then explain the case study to a suitable audience.[116] Building such a case study would involve substantive one-on-one interaction between a learner and a retiring analyst. A case study serves to concentrate both parties on a single series of related issues to make the most of the time available. Building such a case study would have an added advantage of creating an important artifact from which others can learn. Since a learner starts with the background and experience he or she brings to the table and ends with a finished case study, whatever the level of existing knowledge, it will necessarily be engaged. The limited time available creates a sense of urgency and the learner's desire to avoid embarrassment serves as motivation. Having to explain the case study also ensures that aspiring analysts learn with understanding. "Explanation depends, of course, on understanding: if you do not understand something, you cannot explain it."[117] It is estimated that significant knowledge transfer could be accomplished in as little as *one or two years* with a rigorously structured case study approach.

Limited Time Available Case. What if there is very limited time available for substantive one-on-one interaction? One idea is to have the retiring expert write up his or her experiences in a document or memoir. Unfortunately, this is not a high bandwidth option and the ease with which one can learn from such a document depends on the expert's skill as a writer. Another idea is to videotape interviews or panel discussions with experts or panels of experts.

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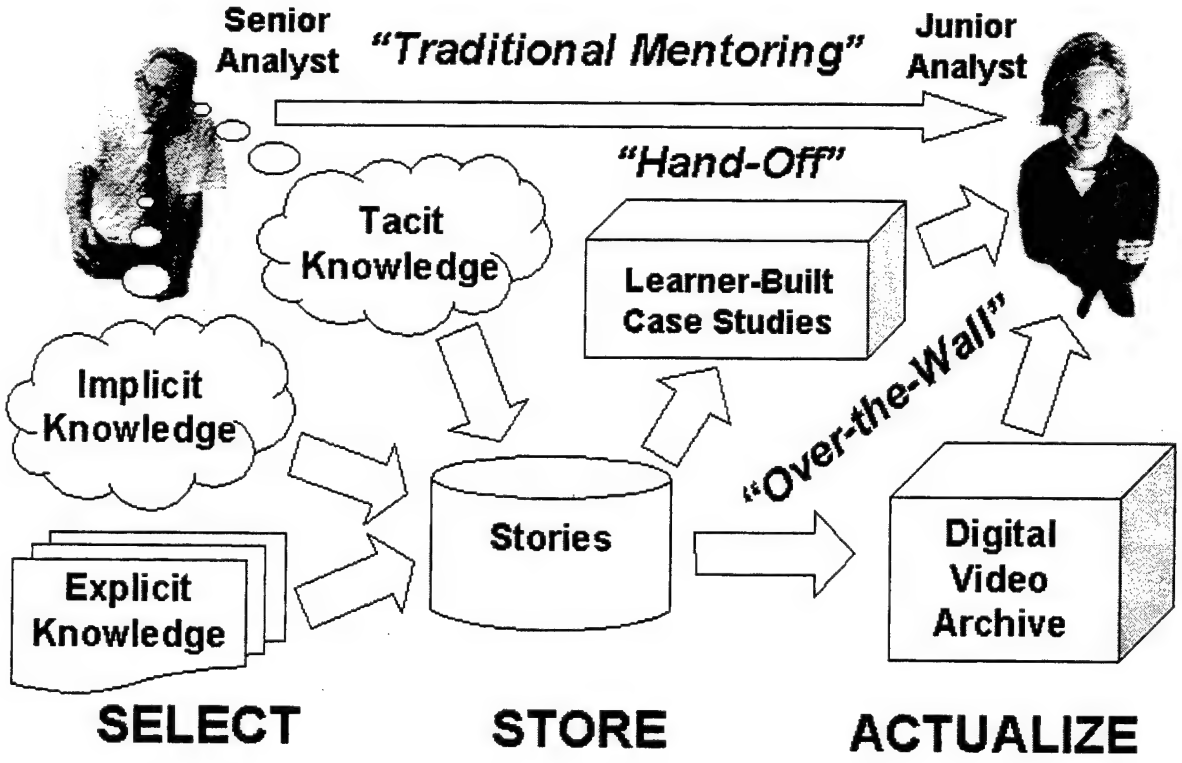
[116] This idea originated independently in discussions with Professor Jim Fitzsimonds of the Naval War College and in interviews conducted with intelligence analysts at ONI.
[117] Johnson-Laird, *Mental Models*, p. 2.

Videotaping efforts to capture knowledge at DOE and NAVAIR were discussed in the previous section. In the more sophisticated forms of this approach, the videos are digitized and transcripts are created to allow searchable access over a computer network.

The combination of these three approaches: *traditional mentoring*, *learner-built case studies*, and *digital video archiving* can be viewed as a three-pronged model for knowledge preservation. Figure 8 shows the relationships between experts, learners, knowledge, and stories. Learner-built case studies can be viewed as a "hand-off" approach because they make use of

Figure 8

Three-Pronged Model for Knowledge Preservation



one-on-one interaction between a retiring expert and a learner. The digital video archiving can be viewed as an "over-the-wall" approach because it can be used by learners without having one-on-one interaction with a retiring expert.

The time frames suggested above are notional, and some experts may use all three approaches before they retire. For example, an expert who is planning to retire in five years may enter into a mentoring relationship with a learner today. Two and a half years later the expert may work with another learner to build a case study and, finally, before the expert retires, digital videos may by created to capture knowledge using this approach as well. Having introduced a three-pronged model it is appropriate to consider what is involved with each prong.

Traditional Mentoring. Traditional mentoring can be formal or informal. In other words, the mentor and mentee can be paired together and enter into formal written mentoring agreement or they can seek each other out and begin a mentoring relationship without a written agreement. Either way, mentors act as informal teachers and coaches to transfer knowledge. The knowledge transferred between a mentor and mentee can be in the form of feedback or guidance on how to solve problems. Problem solving guidance is usually provided only after the mentee has struggled for some time with a problem. Advice on how to maneuver and function in the bureaucracy is another form of knowledge mentors provide to mentees. Other than direct experience, this can be the only way to acquire this kind of knowledge.[118]

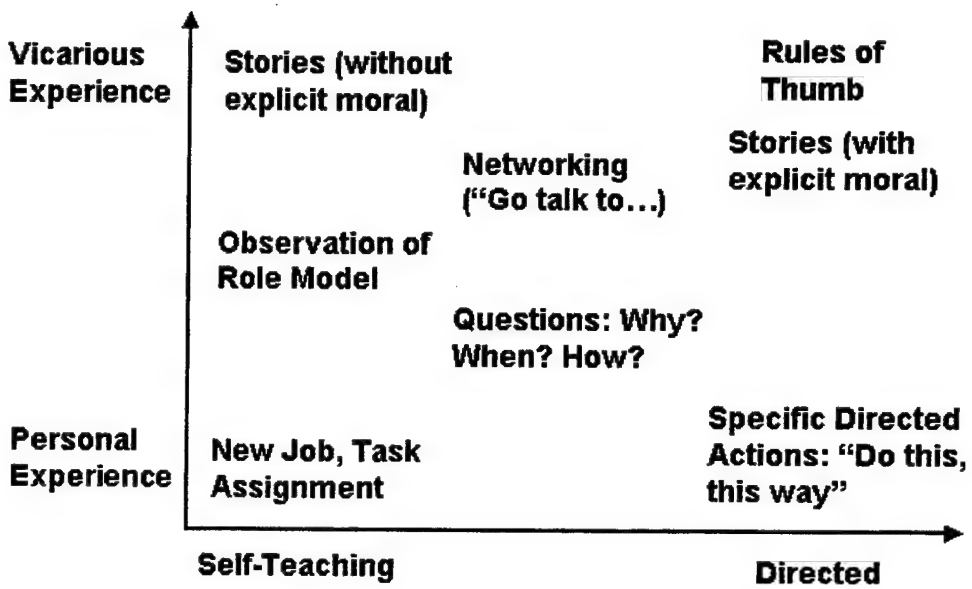
Swap et al., note that mentors use various teaching techniques but most can be characterized using two dimensions. The first is *experience*. This includes a mentee's *personal experience*, often guided by the mentor, and *vicarious experience* or the experiences of others. Vicarious experiences can be the mentor's experiences or the experiences of others that the mentor relates to the mentee. The second dimension is *direction in teaching*. This can take the

[118] Swap, "Transferring Tacit Knowledge Assets."

form of either *self-directed* teaching or instruction *directed by the mentor.* [119] These mentor/mentee interactions are shown in figure 9.

Figure 9

Mentor/Mentee Interactions.



SOURCE: Adapted from Swap et al (2001)

There are many examples of mentoring programs to draw ideas from to establish a traditional mentoring program. The Department of the Navy Human Resources Office has a web site and has developed a mentoring handbook.[120] The National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center uses mentoring to develop project

[119] *Ibid.*

[120] The Department of the Navy Human Resources web site and mentoring handbook are geared toward leadership development. However, many of the same principles apply to mentoring to transfer expertise. <http://www.donhr.navy.mil/Employees/cld.asp> and <http://www.donhr.navy.mil/managers/menthb.pdf> [May 20, 2002].

managers and technical staff and their web site does a good job explaining the relationship between and responsibilities of mentor, mentee, and the mentee's supervisor.[121]

Learner-Built Case Studies. Having a learner build and explain one or more case studies based on the experiences of a retiring expert is an approach intended to accomplish several things. First, it makes the most of the limited time available by focusing the learner and the retiring expert on one specific example that is treated in depth. Second, the learner and the retiring expert work together to document one case from the expert's background. This involves purposeful one-on-one interaction which is a goal from the knowledge transfer model (figures 5 and 6). Third, whatever the level of a learner's existing knowledge and experience, it will be engaged as the starting point leading to the finished case study. Finally, the end product will serve to capture and document important knowledge from the retiring expert that can be used by other learners.

There are many examples of case studies. This is a popular teaching technique at business schools, and the Naval War College uses case studies in its Policy Making and Implementation course.[122] The Central Intelligence Agency (CIA) has developed several case studies in intelligence that can also be used as models.[123]

The retiring expert should identify the case study for the learner to build. It is suggested that future relevance and the availability of supporting materials (including mental recollections and documents) be used in identifying candidate cases for study. Interview techniques such as

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[121] See <http://fpd.gsfc.nasa.gov/cd/mentors.html> [May 16, 2002].
[122] Valerie J. Lofland and David A. Williams eds., *Case Studies in Policy Making and Implementation 5th Edition* (Newport, RI: The Naval War College, 2001)
[123] CIA Case Studies in Intelligence are available over Intel link at <http://www.csi.cia.ic.gov/studies/vol41no1/index.html> [April 3, 2002]

cognitive task analysis to elicit knowledge can also be used to help build the case study.[124] The use of narrative or story-based construction is recommended for the reasons stated previously.

Digital Video Interview and Story Archive. In its simplest form, this method of knowledge capture consists of video taping sessions with an expert or panel of experts as they discuss stories of how they solved difficult or puzzling problems, how they were surprised by unexpected events, and how they used innovative techniques to improve performance. The resulting library of video tapes are not the easiest form for learners to access. It is not possible for learners to easily search video tapes, and they often have to go to a central location to view them. To overcome these handicaps, products have been created to digitize the video so learners can search and view the interviews over a computer network at their desks. I call this third prong of the three-pronged model the "Over-the-Wall" approach of knowledge preservation because it can be used without one-on-one interaction between a learner and a retiring analyst.

Producing videos of retiring experts telling stories and being interviewed is an approach that provides a relatively high bandwidth learning channel when one-on-one interaction between experts and learners is not possible. Selecting appropriate stories and indexing them are key ideas to make the videos more useful as learning tools.

Again, the retiring expert will need to help identify the stories to record. It is suggested that future relevance be used as a guide in selecting stories. Interview techniques such as cognitive task analysis to elicit knowledge can also be used to identify stories and important points to emphasize.[125] Indices must then be created to assist in on-line retrieval. One way to

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[124] Information on interview techniques can be found at the CTA Resource web site <http://www.ctaresource.com> [January 15, 2002] and the Navy's Office of Training Technology <http://www.ott.navy.mil> [January 15, 2002]

[125] *Ibid.*

identify indices is by conducting a knowledge audit to identify specific examples from categories such as diagnosing and predicting, perceptual skills, tricks of the trade and when to apply them, improvising, and recognizing anomalies.[126] These categories are given as examples. There undoubtedly other equally valid categories that can be used. These examples can serve as candidate indices that the retiring expert can use to think of stories that serve to illustrate expertise related to the categories and to ensure these points are captured in stories.

Making digitized video clips available over a computer network makes the knowledge easier to access and allows specific topics to be viewed without sitting through an entire tape. There are products on the market designed to produce and distribute this type of digital video.[127] NASA's Goddard Space Flight Center uses story-based digital video clips to preserve lessons learned from various project managers. Readers can get a flavor for this approach by sampling some video clips of Jerry Madden, a retired NASA project manager, telling stories and relating knowledge from his career.[128]

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[126] Laura G. Militello and Robert J. B. Hutton, "Applied Cognitive Task Analysis (ACTA): A Practitioner's Toolkit for Understanding Cognitive Task Demands," *Ergonomics* 41 (1998): 1618-1641.

[127] See <http://www.convera.com> [April 23, 2002].

[128] See <http://fpd.gsfc.nasa.gov/cd/video.html> [May 16, 2002].

Summary. Steps for each approach in the three-pronged model are summarized in table 2. The time frames overlap and should not be taken as hard and fast values. There is flexibility for an organization to employ these approaches based on the nature of the expertise involved, the particular retiring experts and learners, and experience and lessons to be learned using these approaches. Both the over-the-wall and hand-off approaches require some up front work to

Table 2

Steps in Three-Pronged Model

	Time Available		
	Less than 1 year	1 to 3 years	More than 3 years
Name	*"Over-the-Wall"*	*"Hand-Off"*	*Traditional Mentoring*
Steps	• Identify key indices • Identify interesting stories • Make videos • Create digital archive • Learners use	• Identify key indices • Identify interesting stories • Learner builds case study • Learner presents	• Identify mentor-protégés • Self vs directed teaching • Personal vs vicarious experience

identify the indices that are key to how the expert's knowledge is organized and used. Also, stories with the most interesting and likely-to-be-relevant knowledge need to be identified in the first step.

In this section, a generalized model of knowledge preservation was developed building on a simplified model of knowledge transfer derived from the concepts of logical depth and

exformation. A case was made to adopt a story-based approach to learning. These ideas were combined to arrive at a three-pronged model based on how long retiring experts are available to work face-to-face with their replacements.

Although the focus here has been on the transfer of knowledge between people, one should not discount the value of an archiving effort for data and information. Archiving makes the artifacts of technical knowledge more readily available. Many of the lessons learned in using the three-pronged model will point toward the data and information that properly belongs in an archive. However, an archive by itself will not serve to transfer knowledge from one head to another. In the next section the issues of practicality that must be considered to put this knowledge preservation model into action are discussed.

SECTION VI

PUTTING THE MODEL INTO ACTION

Knowledge Superiority based on Maritime Intelligence ...
... Enabling Dominance from the Sea.
--Inscription at ONI Headquarters

Introduction. In this section the discussion turns to how to put the three-pronged knowledge preservation model into action at the Office of Naval Intelligence (ONI). The objective is to frame specific answers to the questions raised in section III. What constitutes expertise in conducting Naval intelligence analysis and how does one identify and prioritize expertise worth preserving? How can expertise-related knowledge be captured in a form that fosters learning and transfer? What characteristics do potential solutions need to possess to be seen as practical by analysts and senior Navy management? The answers to these questions will be framed around the processes and model explained in the previous section. The lessons from industry, science, and government will also be used to guide the following discussion. Some ad hoc knowledge preservation initiatives, already taking place at ONI, are discussed, and some ideas for how these initiatives fit into the model-based solution are presented. The thorny issues of cost, schedule, and culture are briefly treated and some Rough Order of Magnitude (ROM) cost estimates are presented along with their underlying assumptions.

Characteristics of Expertise in Naval Intelligence. To select specific expertise-related knowledge for preservation, it must first be identified. Are there characteristics of expertise in Naval intelligence that are shared with expertise in other fields? Researchers have identified several "hallmarks" of expertise that apply to expertise in general and have implications that are

useful for identifying expertise-related knowledge and capturing knowledge that includes elements that benefit learners.[129] The hallmarks of expertise are:

- Experts notice features and meaningful patterns that are not noticed by novices.
- Experts have acquired a great deal of content knowledge that is organized in ways that reflect a deep understanding of their subject matter.
- Experts' knowledge cannot be reduced to sets of isolated facts or propositions but, instead, reflects contexts of applicability: that is, the knowledge is "conditionalized" on a set of circumstances.
- Experts are able to flexibly retrieve important aspects of their knowledge with little attentional effort.
- Though experts know their disciplines thoroughly, this does not guarantee that they are able to teach others.
- Experts have varying levels of flexibility in their approach to new situations.[130]

It is reasonable to assume that these hallmarks apply to expertise in Naval intelligence. Specific characteristics of expertise in Naval intelligence analysis are tied to each subspecialty. For example, these specifics include the features and patterns a senior submarine analyst might notice in raw source data that a novice would not notice. This includes specific details of the contexts under which certain rules of thumb or analytical methods apply. These generalized hallmarks and the specific details that emerge when they are applied to the subspecialties within Naval intelligence constitute the characteristics of expertise in conducting Naval intelligence analysis.

Equipped with some idea of what constitutes expertise in Naval intelligence analysis, how does one go about selecting expertise-related knowledge worth preserving? In other words, how does one identify and prioritize expertise?

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[129] Bransford et al., *How People Learn*, p. 31.
[130] *Ibid.*, p. 31.

Identifying and Prioritizing Expertise: Selection. Preserving knowledge costs time and money. Therefore, the focus needs to be on preserving knowledge that will be useful in the future. The question then becomes how to make future relevance the driving consideration of the knowledge to be preserved. An agency or organization's strategic planning efforts and strategic plans provide one source of high level guidance. Although ONI does not have a current strategic plan, *Joint Vision 2020* and the *Navy Strategic Planning Guidance* can offer some broad areas to act as guidance.[131] Other approaches that can be used to get a handle on future relevance at the organizational level include scenario planning techniques and capability-based approaches like the Design Reference Mission.[132] Yet another approach for understanding the future relevance of knowledge is to adapt a threat projection methodology used to estimate the timeline and numbers associated with the fielding of an enemy weapons system to focus on future Naval intelligence capabilities. A candidate threat projection methodology to adapt for this purpose is

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[131] Joint Vision 2020 is the Department of Defense's strategic vision for the future. It was written by the Chairman of the Joint Chiefs of Staff. Each Service has developed a companion vision document as well. These documents can be accessed at <http://www.dtic.mil/jv2020/> [May 28, 2002]. See Chief of Naval Operations, *Navy Strategic Planning Guidance with Long Range Planning Objectives*, April 2000. <http://www.hq.navy.mil/n3n5/files/NSPG2000.pdf> [May 28, 2002].

[132] For an example of a scenario technique that uses vision stories to better understand the future see Ira M. Levin, "Vision Revisited: Telling the Story of the Future," *The Journal of Applied Behavioral Science* 36 (2000): 91-107. The Design Reference Mission (DRM) concept originates from the Systems Engineering community. DRM has been used by the Navy to understand future force requirements at the battleforce and platform levels. DRM is aimed at characterizing the future threat and operating environment for use with requirements definition, concept development, and trade study analysis. Since a number of DRMs have been created for Naval warfare areas, these same products could be used to gauge future Naval intelligence requirements, capabilities, and the potential relevance of knowledge. See Fred R. Skolnick and Phillip G. Wilkins, "Laying the Foundation for Successful Systems Engineering," *Johns Hopkins APL Technical Digest* 21 (2000): 208-216 and Christine Salamacha, Sterling Smoot, and Kathleen Farris, "C4ISRT in an Operational Context," *Johns Hopkins APL Technical Digest* 21 (2000): 378-386.

one developed by the Naval Postgraduate School which uses the past as a key to the future.[133] The strength of this type of methodology lies not in its accuracy in predicting the future, but in the value of having the rationale and reasoning behind the projections documented so that unanticipated changes can be incorporated and independent scrutiny of the projections can be made. These features make it well suited for estimating the analysis capabilities needed in the future and the potential relevance of expertise-related knowledge being considered for inclusion in a knowledge preservation program.

The discussion of knowledge preservation processes in the previous section suggested creating "selection rules" to determine knowledge worth preserving. Such a set of rules could be created for ONI. One rule might be to perform periodic Naval intelligence analysis capability assessments for each critical area of interest using some combination of the methods discussed above. Example areas of interest include Naval guns, directed energy weapons, submarines, surface ships, Naval Surface to Air Missiles (SAMs), and cruise missiles. The frequency of the assessments could vary depending on the technologies involved, but could be done once every five years for example.

Further selection rules could be developed from the results of these capability assessments to pinpoint specific analytical expertise. Selection rules must be flexible, since it is difficult to anticipate all areas of knowledge that will be needed in the future. Selection rules and

[133] D. K. Abernathy, "Threat Projections – What You Don't Know Can Hurt You." Unpublished Paper, Naval War College, Newport, RI, 28 October 1982, quoting Dr. R. Stolfi and Dr. P. Wand, "A General Methodology for Forecasting the Technological Threat from the Soviet Navy," instructional material provided to the author during a class held at the Naval Intelligence Support Center, September 27-28, 1976.

approaches for estimating the future relevance of knowledge are useful tools, but people must be tasked to use these tools for appropriate knowledge to be selected for preservation.

Assigning roles and responsibilities for knowledge preservation to knowledgeable individuals from "centers of competency" in an organization is an idea that should be adopted by ONI. Fortunately, just such a group of knowledgeable individuals have been formed into a team to study knowledge preservation and similar issues. They are the so called "Subject Matter Experts" (SME) group at ONI. These are the experts who are in the best position to judge the expertise that is most likely to be relevant in the future. To select knowledge worth preserving one should "ask the experts."

Asking the experts is a sensible way to identify the most obvious expertise worth preserving, but what about less obvious expertise? A strategy that can be used here is to look for the hallmarks of expertise listed above. In some cases, this level of expertise may exist in analysts who are far from retirement. Preserving some of their knowledge today may be worthwhile in the event they leave the organization or take another assignment. Also, the systematic preservation of this type of expertise as it is identified may be easier than waiting until later and may lead to the sharing of best practices in other areas of intelligence analysis.

Capturing Knowledge in a Form That Fosters Learning and Transfer: Storage. Once Knowledge has been selected to be preserved, it must be captured in a form that fosters learning and transfer. The knowledge must be stored. This can be accomplished in a number of different ways but the discussion here focuses on learner-built case studies and video interviews, both of which use stories to capture and transfer knowledge.

Planning and pre-capture interview techniques are recommended to identify relevant stories and to ensure the knowledge captured includes contextual information, cues for

metacognition, tips on how to organize the knowledge, and key indices that can be used for search and retrieval.

Interview techniques based on Cognitive Task Analysis (CTA) methodologies have been used to elicit expertise-related knowledge in a number of different settings.[134] One approach is the Critical Decision Method (CDM) which uses a retrospective interview strategy and a series of cognitive probe questions to explore different aspects of the decision-making process. This technique has been used to elicit expertise-related knowledge from fire ground commanders, neonatal intensive care unit nurses, in Army command and control settings, and military ground navigators.[135] Another approach is to adopt the Applied Cognitive Task Analysis (ACTA) methodology developed by Militello and Hutton.[136] ACTA is a simplified methodology that makes use of structured activities an interviewer and an expert work through to elicit knowledge. One activity is the creation of task diagrams where an expert's approach to a task is subdivided into between 3 and 6 steps to provide a manageable, yet meaningful, level of detail to begin understanding how the expert conducts an important task. Another activity is the knowledge

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[134] The Navy's Office of Training Technology web site includes an introduction to these methods for knowledge elicitation with examples and several aids for eliciting declarative, procedural, and strategic knowledge. <http://www.ott.navy.mil/View_detail.cfm?RID=TTE_OT_1000012> [May 28,2002]

[135] For the relationship between the CDM and stories and the use of CDM with neonatal nurses and fire ground commanders see Klein, *Sources of Power*, pp. 189-190. For the use of CDM in Army command and control settings see Gary A. Klein, "The Development of Knowledge Elicitation Methods for Capturing Military Expertise," U.S. Army Research Institute for the Behavioral and Social Sciences, ARI Research Note 96-14, Fort Leavenworth, KA, January 1996. For the use of CDM with military ground navigators see Barry Peterson, Jason L. Stine, and Rudolph P. Darken, "Eliciting Knowledge from Military Ground Navigators," The 5th Naturalistic Decision Making Conference, Tammsvik, Sweden, May 26-28, 2000. <http://www.movesinstitute.org/darken/publications/ndm5.pdf> [May 28, 2002].

[136] Militello and Hutton, "Applied Cognitive Task Analysis," *Ergonomics* 41 (1998): 1618-1641.

audit where probe questions are used to explore important expertise-related aspects of knowledge including "diagnosing and predicting, situation awareness, perceptual skills, developing and knowing when to apply tricks of the trade, improvising, metacognition, recognizing anomalies, and compensating for equipment limitations."[137]

Lessons from the science of learning discussed in section IV suggest that these pre-knowledge capture activities and interviews should be structured to obtain a map of the factual knowledge required, details on the contexts in which the knowledge applies, and cues for assessing a learner's progress toward understanding.

Case Studies. In the learner-built case studies, a learner works one-on-one with a retiring senior analyst to document a significant case study from the senior analyst's background and career. The learner will document the case study and then explain it to a suitable audience. Although the best case study to be captured may already be apparent to the retiring analyst, the interview techniques discussed above should still be used to bring out important details. And when a retiring expert has trouble selecting a case for study, the interview techniques can be used to help identify a suitable case.

Once key rules of thumb, tricks of the trade, and contextual knowledge have been identified in the planning and pre-capture interview activities, these elements should be weaved into the story line as the case is constructed. Where including these elements directly in the narrative becomes cumbersome, they should be included as appendices and cross referenced so learners can gain the benefit of learning from a story and have access to critical supporting information for further study.

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[137] *Ibid.*

Having learners explain their case studies provides incentives for them to learn with understanding. These incentives include creating a sense of urgency and a desire to avoid embarrassment. The existing practice at ONI where analysts present a "vignette" of how a foreign weapon system works to the admiral could be used as a forum for learners to explain the case studies they have developed.[138] An additional benefit form the learner-built case study is that it documents this knowledge and makes it available for others to read and study in the future.

Video Interviews. Using video to capture knowledge from interviews with retiring analysts is one way to transfer their knowledge without direct one-on-one interaction between the learners and retiring analysts. The planning and pre-capture interview techniques described above also apply here. These activities can help select the stories to record and identify the key indices, contextual knowledge, and metacognition cues learners need to more easily grasp the material and reach the deep level of understanding.

Once the stories and key information have been identified, storytelling-interview sessions can be videotaped. The stories can be told ad lib or from a script, depending on what makes the retiring analyst more comfortable. When a script is not used, an interviewer can use probe questions to prompt the retiring analyst to elaborate on key points that do not get covered in the ad lib portions of a storytelling session.

Video from the sessions can then be edited to clean up miscues and retakes from the storytelling-interview sessions. One senior ONI analyst expressed concerns about the ability of the retiring analyst to edit and reflect upon the end product from the video sessions.[139] However, these concerns can be addressed by involving senior analysts in the editing and post-production

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[138] ONI representatives, Interview by author, Suitland, MD, 3 April 2002.
[139] *Ibid.*

activities. Although the knowledge capture team should have training and experience with video editing, the senior analyst, as the source of the knowledge being captured, is in the best position to guide the editing process. In some cases, involving a senior analyst in a reflective editing process may lead to further video recording sessions to improve segments or capture new aspects of the stories.

If a digital video archiving and retrieval system is used, the videos are digitized and software is used to create transcripts that can be searched on-line to select content for viewing. Of course, security and access controls must be used and should be thoroughly scrutinized for potential vulnerabilities.

Several learning possibilities exist once the videos become available. Learners can use the video stories as part of a program of self-study or the videos can be incorporated into more formalized instructional classes. Because of the indexing and digital access, learners can enter the video stories based on an index related cue such as a "rule of thumb" or the videos can be viewed in their entirety. This degree of flexibility suggests that analysts should experiment with these capabilities to explore what works best for them.

Study Initial Learners to Develop Pedagogical Content Knowledge. In addition to analysts experimenting with video capabilities, efforts should be made to study initial learners to identify the roadblocks and difficulties they encounter in understanding the knowledge under study. This pedagogical content knowledge can then be used to make improvements in the learning materials and develop aids such as computer simulations to help learners overcome barriers to learning and understanding. Developing pedagogical content knowledge requires effort and resources. Therefore, only knowledge that will be used by several different learners justifies this level of investment.

Archiving of Documents, Files, and Records. Although archiving of documents, files, and records is not seen as the principal purpose of the three-pronged model developed in this study, archiving reinforces and complements knowledge preservation. The stories and knowledge captured in case studies and video will often reference documents, files, and records. These artifacts provide the source materials that learners can use to more fully explore aspects of stories and to gain ideas for how to adapt the knowledge learned to their own projects.

One senior analyst interviewed by the author explained that each community of analysts at ONI has developed its own system for storing and filing data and information related to their projects.[140] This often results in working materials and project files being stored in desk drawers and nearby filing cabinets. A consequence of these practices is that analysts are limited in their ability to efficiently conduct searches for specific information and to take advantage of data-mining technology. Some knowledge becomes essentially inaccessible while an analyst is out of the office on vacation. A digitized, on-line solution could make this knowledge more accessible and lead to improved analytical capability through increased sharing of ideas and information. This same senior analyst said:

> In the surface community, they have 50 filing cabinets in a central location that are organized in a logical manner. This has paid off many times in the past because of the ease of finding what you are looking for due to the organization and accessibility. An electronic version of something like the surface community filing cabinets would go a long way toward fixing these shortcomings.[141]

This suggests that the surface community's filing cabinets could be studied as a model to develop an electronic knowledge management solution for the analysts at ONI. One way to achieve this is by fielding a pilot project with heavy analyst involvement in the prototyping stage

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[140] *Ibid.*
[141] *Ibid.*

to ensure the ease of use, level of structure, and degree of flexibility required for success are designed into the solution before committing the larger investment required to put this knowledge on-line.

Adopting a Process Orientation Towards Intelligence Analysis. One of the guidelines for successful knowledge management projects discussed in section IV (see pages 26, 27) was to adopt a process orientation. Intelligence analysis is a knowledge intensive endeavor, so it is not surprising to see a process perspective being advocated to improve the overall quality of intelligence analysis and serve as a template that analysts can use to guide their own efforts.

For these reasons, another senior ONI analyst is conducting an "analysis of analytical tradecraft" with an eye towards identifying a "critical path" for analysts to follow. This senior analyst is establishing some "corporate standards on how analysis is done" as the first step in defining a process of analytical tradecraft.[142] For example, this might include quantifying and validating fifteen or so common attributes a good analytical process must contain. The development of standards are followed by a more detailed "process of analytical tradecraft." The logic behind these process initiatives is that by following a sound process, analysts should be led to the right answers more often than not. Following a sound process could also lead to the adoption and sharing of analytical best practices by more analysts, and it could result in greater consistency in how analysis is documented. Better documented analysis should result in analysis that better stands up to scrutiny and is easier for fellow analysts to understand and verify.

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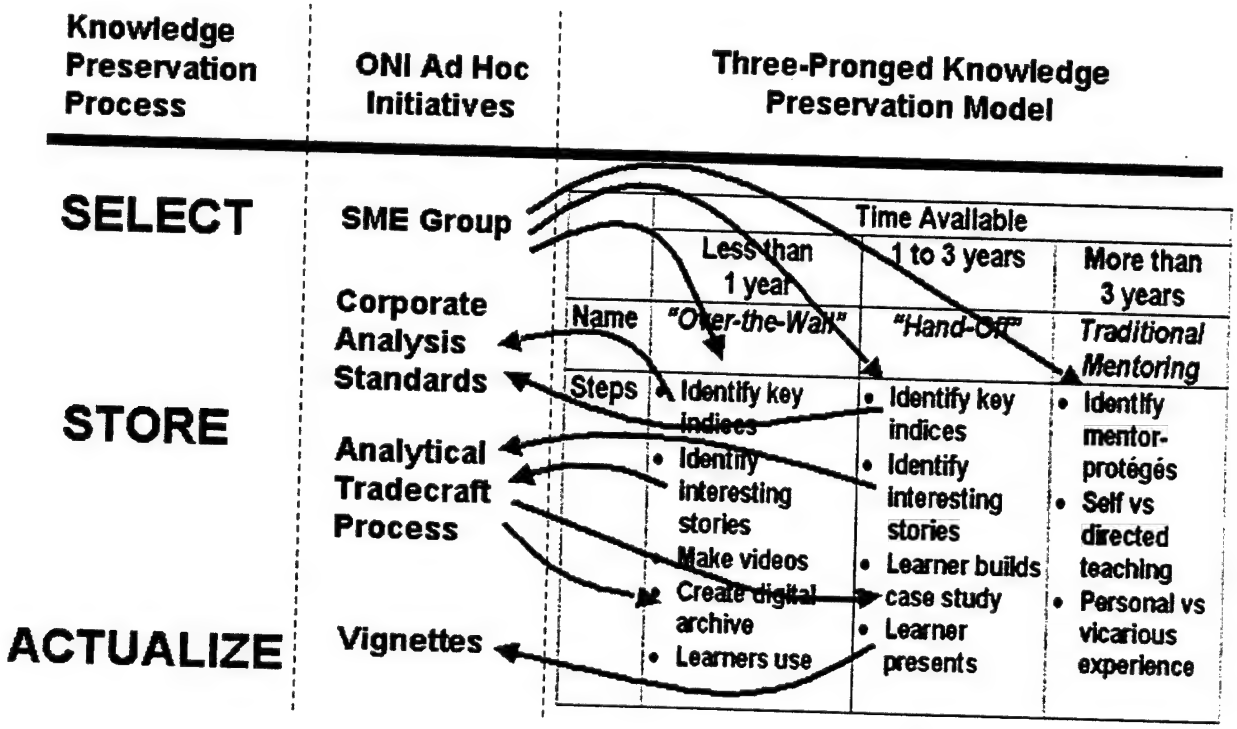
[142] *Ibid.*

Ad Hoc Initiatives. Several ad hoc knowledge preservation initiatives being pursued at ONI can play a synergistic role within the three-pronged knowledge preservation model. Figure 10 shows how ONI ad hoc initiatives relate to the various steps of the three-pronged model's select, store, and actualize processes. As related above, the SME group can help identify knowledge worth preserving by identifying analysts with expertise and can help to establish the future relevance of analytical knowledge. The key indices identified in the knowledge capture activities of the video and case study stories can be used to help develop the corporate analysis

Figure 10

How ONI Ad Hoc Initiatives Fit Into the Three-Pronged Model



standards. The interesting stories that are identified can be used to develop and refine both the corporate analysis standards and the analytical tradecraft process. The analytical tradecraft process can point toward the video and case study stories as specific examples of the process in

action. Finally, the "vignettes" can be used as a forum for learners to explain the case studies they have developed. Having addressed the selection of knowledge worth preserving, the discussion now turns to how to make the solution practical and how to actualize it.

Characteristics of Practical Solutions: Actualize. For a knowledge preservation solution to be seen as practical by analysts and senior Navy management, both groups will need to perceive the value provided by the solution. The top concerns voiced by analysts relate to ease of use and how much using the solution can help them perform their jobs.[143] Top concerns voiced by ONI management include a desire that the solution be "as non-intrusive as possible" and that the solution be effective in preserving knowledge.[144]

Top Analyst's Concerns. Concerns analysts have over ease of use can be addressed by beginning small with pilot projects and prototypes that involve analysts to shape the "user interface" and resulting system behavior. This approach requires a balance to obtain enough analyst involvement to ensure ease of use without placing excessive demands on their time. For the knowledge preservation solution to be a success, some knowledge workers must be dedicated full time to the project.

Concerns analysts have about the solution being able to help them do their jobs will depend on the quality of the story-based knowledge captured and how easily the end products are indexed and can be searched. The quality of the knowledge captured will depend, in part, on the ability of those charged with selecting knowledge worth preserving to select the right knowledge and by the skill of those charged with capturing the knowledge to collect the contextual knowledge and metacognition cues that help learners to truly understand a subject.

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[143] *Ibid.*
[144] *Ibid.*

Top Management Concerns. Management concerns about the solution being "as non-intrusive as possible" hint at an Artificial Intelligence (AI) based solution that could "follow analysts" around for the last few years of their careers to capture their expertise. Their captured expertise could then be used by computer support systems and to help train a new generation of analysts. Such an approach would appear passive and non-intrusive to an analyst by always staying in the background collecting and organizing information.

While such applications may appear in the future, they are not available today. Products such as Tacit Knowledge System's KnowledgeMail™ are a step in this direction.[145] Here is how the product has been described:

> Tacit has developed a system called KnowledgeMail that automatically discovers and exchanges expertise under the secure control of individual users, and integrates profiling and expertise search capabilities with a broad range of desktop applications. The system automatically and continuously discovers the expertise and work focus of everyone in the enterprise and then brokers connections among people so they can make timely, informed decisions about critical and complex needs.[146]

While the capabilities of KnowledgeMail™ are no doubt impressive and to some degree unprecedented, when one gets down to the product's essence, it is no more than a very sophisticated knowledge map. It is a knowledge map that helps people find each other in novel and timely ways while continuously updating the map to reflect changes in the terrain. Unfortunately, the actual knowledge stills resides in the experts' heads, and when they retire it walks off the map with them. The knowledge map then points to an empty landmark. As appealing as this type of AI-based solution appears on the surface, it is hard to conceive of automated software technology that can account for the properties of the "tree of talking"

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[145] Kerry Gildea, "CIA Gets Next Generation Information Technology Tools," *C4I News*, December 13, 2001.
[146] *Ibid.*

communication model described in the previous section, i.e., software capable of "tapping into" the exformation from both learners and experts. Based on the science of learning, such software would need to elicit the contextual knowledge and metacognition cues that people use to learn with understanding. One conclusion developed in this study suggests that ***more*** human interaction, ***not less***, makes for effective knowledge preservation and transfer.

Management concerns about the solution being effective at preserving knowledge can be addressed by following a process that balances the problem's knowledge, learning, assessment, and cultural dimensions. The knowledge preservation model developed in this study report strives to achieve this balance. Other issues of practicality include the solution's affordability, schedule, and cultural acceptance. The following discussion explores these issues and presents some ideas for how to manage them.

Affordability. Affordability is one of those terms that can mean different things to different readers. The Department of Defense uses the following definition:

> Affordability is the degree to which the life-cycle cost of an acquisition program is in consonance with the long-range investment and force structure plans of the Department of Defense or individual DoD Components.[147]

The long-range investment and force structure plans of the U.S. Navy must include maintaining and bolstering capabilities for Naval intelligence analysis. The shift from a blue water force towards a forward-deployed force focused on the littorals and the proliferation of high technology weapons and greater numbers of potential adversaries dictate that the demands

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[147] Department of Defense, *Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS) Acquisition Programs* (DoD 5000.2-R, April 5, 2002), p. 70. <http://dod5000.dau.mil/DOCS/Master.020405.Regulation.doc> [May 30, 2002].

on Naval intelligence are ***greater*** today than during the Cold War. Consider the following excerpt from the *Navy Strategic Planning Guidance* document:

> ... our potential adversaries will continue to pursue area denial strategies over the next 15 to 20 years. These challenges will primarily be land-based and in the near-coastal regions. Some potential adversaries will expand their denial strategy to include space and cyberspace as well as adjacent sea and air space to provide a defense in depth. Both the sophistication and the performance of weapons will increase substantially. Platform and weapons survivability will increase through multi-spectral signature control and advanced countermeasure designs. Increasingly, these weapon systems and platforms will be supported by more sophisticated sensor systems. This requires sophisticated counter-targeting systems and doctrine to enable U.S. and allied forces to defeat such weapons. There will be significant threats to forward presence forces from defensive mine warfare; massed small boat attacks employing man-portable weapons; advanced air, surface and submarine launched cruise missiles; and potential for chemical/biological weaponry. Another area of concern is the availability of advanced air independent propulsion systems for submarines.[148]

The picture painted by this excerpt indicates that an investment in preserving and transferring knowledge required to conduct Naval intelligence analysis is warranted. How much should one expect a credible knowledge preservation program to cost? This question is answered by adopting a working definition of affordability and performing a cost analysis.

A working definition of affordability for this study report recognizes the total ownership cost aspects of life-cycle costs, but simplifies the scope to consider mainly recurring and non-recurring program costs. Non-recurring costs refer to the costs associated with acquisition of hardware, software, and the technical support to get a solution up and running. Recurring costs refer to the costs to use and maintain the solution.

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[148] Chief of Naval Operations, *Navy Strategic Planning Guidance with Long Range Planning Objectives*, April 2000, pp. 5-6.

Cost Analysis. There are several cost analysis methodologies that can be used to estimate the costs associated with putting the three-pronged knowledge preservation model into action. The method followed here draws on the *analogy*, *parametric*, and *rule-of-thumb* approaches to cost estimation.[149] The cost analysis starts by focuses primarily on the "over-the-wall" digital video archive component of the three-pronged knowledge preservation model. Then costs for the learner-built case studies and traditional mentoring are estimated.

"Full Blown" Sandia-Like Analogy-based Cost Estimate. An analogy can be drawn between the published figures for Sandia National Laboratory's knowledge preservation program and the costs for a knowledge preservation program at ONI. Annual recurring costs for Sandia's program are estimated to be $1.2 million per year in FY98 dollars. This figure is based on two sources. First, a DOE Inspector General's report that lists an estimate of Sandia's "costs to date" (covering FY94-FY98) as $4.5 million which works out to about $1.3 million per year.[150] Second, a Sandia Program Plan listing knowledge preservation project budget line of $1.2 million per year for FY98 through FY02 in FY98 dollars.[151] $1.2 million in FY98 dollars is equivalent to $1.46 million in FY03 dollars assuming an annual inflation rate of 4%. The Sandia budget also includes the following potentially relevant costs in FY98 dollars:[152]

Search & retrieval tool	$ 1,250K
Automated data conversion	$ 750K
Pilot nonelectronic data conversion	$ 500K
Classified infrastructure	$ 100K
Total	$ 2,600K

[149] For more detailed explanation of cost analysis methodologies and host of other cost analysis-related knowledge see the Defense Acquisition University's web site at <http://center.dau.mil/Topical_Sessions_templates/FM1/learning-script.html> [May 29, 2002].
[150] DOE, *Efforts to Preserve the Knowledge Base*, p. 5.
[151] Sandia National Laboratory, *A Sandia Nuclear Weapon Knowledge Management Program Plan for FY 1998-2003* (SAND97-3083/1 UC-70, February 1998), p. 17.
[152] *Ibid.*, p. 17.

When converted from FY98 into FY03 dollars, using an annual inflation rate of 4%, $2,600K becomes $3,163K. The Sandia budget does not include the cost to line organizations for implementing the program since it is assumed to be included in the cost of "doing business" and the budget does not include normal Human Resources (HR) and Chief Information Officer (CIO) costs since these activities are assumed to be funded separately.[153] The Sandia knowledge preservation program has a heavy emphasis on video with over 2,000 hours of digital video indexed for on-line access.[154] Sandia's knowledge preservation program also includes an active document archiving component. As stated previously, although there are tangible benefits from the archiving of documents, these activities were not included as an integral part of the knowledge preservation model developed for this study report because the archiving of documents is not seen as essential for the transfer of expertise-related knowledge from one analyst's head to another.

Nevertheless, a raw comparison between Sandia's experience and a potential knowledge preservation solution at ONI provides an idea of what a "full blown" knowledge preservation program could cost. Assuming ONI's knowledge preservation program "mirrors" Sandia's allows their budget figures to be converted to FY03 dollars and used directly to estimate the cost of a "full blown" Sandia-like program at ONI. These numbers, in FY03 dollars, are $1.46 million in recurring costs and $3.163 million in non-recurring costs. The non-recurring costs could be spread over several years as the program ramps up while the recurring costs occur every year.

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[153] *Ibid.*, p. 18.
[154] Dan Caterinicchia, "Preserving Knowledge," *Federal Computer Week*, August 13, 2001. <http://www.fcw.com/fcw/articles/2001/0813/mgt-doe-08-13-01.asp> [May 30, 2002].

"Scaled Down" Sandia-Like Analogy-based Cost Estimate. Costs for a "scaled down" Sandia-like solution can be estimated using the analogy method. In this case it is assumed that ONI will not invest in document archiving activities as part of a knowledge preservation program. The Sandia budget figures can then be adjusted by halving the recurring costs to $730K. The rationale for this change stems from the division of costs between video and document knowledge preservation activities. This division is not specified in the Sandia budget, but since both activities are known to be significant and labor intensive endeavors, a logical first order approximation is to divide the recurring cost figure equally. An estimate of the non-recurring costs in this case can be made by using only the Sandia budget figure for the "search and access tool" line. The rationale for this change is that the "data conversion" lines are assumed to be related to document archiving efforts and ONI can leverage Sandia's investment in developing a "classified infrastructure." These assumptions result in an adjusted non-recurring cost of $1,521K in FY03 dollars.

Digital Video Pilot Solution Parametric-based Cost Estimate. Costs for a "pilot" knowledge preservation solution using a parametric method can be made using the following assumptions. Again it is assumed that ONI will not invest in document archiving activities as part of their knowledge preservation program. A pilot installation of Convera's Screening Room digital video archiving and retrieval software will be acquired along with video cameras and editing equipment. Full time personnel dedicated to the project include a Knowledge Manager and a Knowledge Transfer Engineer.[155] Labor costs for these personnel are estimated using the

[155] For descriptions of these job roles see Department of the Navy, *Civilian Career Path Guide for the Management of Technology, Information, and Knowledge*, Vol. II, Career Areas, Knowledge Management, March 2001, pp. KM-1 to KM-3. <http://www.don-imit.navy.mil/contentDownload.asp?theID=04272001GIA4932846> [May 30,2002].

direct labor rates for Space and Naval Warfare System Center, Charleston civil service employees.[156] The Knowledge Manager is assumed to be a DP04 (GS-14) worker with a FY03 direct man year rate of $176K (calculated from the FY02 labor rate accelerated by 4% for inflation). Similarly, the Knowledge Transfer Engineer is assumed to be a DT03 (GS-12) worker with a FY03 direct labor man year rate of $134K. The annual recurring cost is obtained by adding these man year figures together plus another $50K to cover material, training, travel, and miscellaneous expenses. This results in a recurring cost of $360K in FY03 dollars. No per diem or relocation expenses are included in this estimate. The rationale for these numbers is that although contractors or in-house ONI personnel may be assigned to these job roles for the project, their labor rates should be no greater. The non-recurring cost is obtained by adding a $100K for a pilot Convera Screening Room suite to $25K for video cameras and editing equipment. This Screening Room suite consists of a network-equipped server, workstation, and a five-seat user license. The cost drivers for Screening Room are the seat licenses and the digital video storage hardware.[157] This brings the total non-recurring costs to $125K in FY03 dollars.

This figures are summarized below:

Recurring Costs

Knowledge Manager (GS-14)	$ 176K
Knowledge Transfer Engineer (GS-12)	$ 134K
Materials, Training, & Travel	$ 50K
Total	$ 360K

[156] Space and Naval Warfare Systems Center, Charleston, *Fiscal Year 2002 Navy Working Capital Fund Rates for the Space and Naval Systems Center, Charleston, SC* (SPAWARSYSCENNOTE 7600, 10 October 2001).
[157] Alan Smith, telephone conversation with author, 30 April 2002.

Non-Recurring Costs

Convera Screening Room Suite	$ 100K
Video Camera & Editing Equipment	$ 25K
Total	$ 125K

Digital Video Pilot Solution Rule-of-Thumb-based Cost Estimate. Cost for a "pilot" knowledge preservation solution using a rule-of-thumb method can be made using Davenport and Prusak's "$33^{1/3}$ rule."[158] The $33^{1/3}$ rule states that to be successful, a knowledge management project should only dedicate one third of its time, effort, and money towards technology. This rule can be applied in this case by fixing the technology costs at the $125K non-recurring figure used in the parametric estimate above. This fixes the recurring costs or the "non-technology" costs at $250K. Both figures are expressed in FY03 dollars.

The parametric and rule-of-thumb estimates above have centered around the "over-the-wall" digital video archive component of a three-pronged knowledge preservation solution for ONI. Parametric cost estimates for the "hand-off" learner-built case studies and the "traditional mentoring" can also be calculated.

Learner-Build Case Study Parametric-based Cost Estimate. For the learner-built case studies, the Retrieval Ware part of Convera's Screening Room software can be used to put the case studies on-line. Although the case studies could be created strictly by the learner-retiring analyst team without outside assistance, professional help with interview techniques, knowledge elicitation, and on-line conversion should be included, at least initially, to help ensure project success. Therefore, to capture these costs the estimate assumes one half man-year of a GS-14 Knowledge Manager. When these labor costs are combined with $15K to cover materials,

[158] Davenport and Prusak, *Working Knowledge*, p. 173.

training, travel, and miscellaneous expenses a recurring cost of $103K in FY03 dollars is obtained. The non-recurring costs are assumed to be nil since the Convera Screening Room suite cost is captured in the digital video archiving estimates. These figures are summarized below.

Recurring Costs

Knowledge Manager (GS-14) half time	$ 88K
Materials, Training, & Travel	$ 15K
Total	$ 103K

Traditional Mentoring Parametric-based Cost Estimate. For traditional mentoring, the bulk of the activity occurs between the mentor and the mentee. Therefore, the costs associated with traditional mentoring are almost entirely buried in the costs of conducting normal business. That said, the traditional mentoring program at ONI could benefit from a more formalized structure, from counseling and training of participants, and from active efforts to broker mentoring pairs. One option is to redirect existing HR personnel to provide these services. The traditional mentoring component of a knowledge preservation program will not require additional funding if improvements to the mentoring efforts are not made, or if existing HR personnel are redirected to make the improvements. However, since improvements would be beneficial and HR personnel are undoubtedly facing their own challenges, it is proposed to dedicate one half a man-year of a GS-14 Knowledge Manager to the traditional mentoring component of a knowledge preservation program. This would allow one knowledge worker to split her time between learner-built case studies and traditional mentoring. Using the same logic as above, when this labor cost is combined with $15K to cover materials, training, travel, and miscellaneous expenses a recurring cost of $103K in FY03 dollars is obtained. Again, the non-recurring costs are assumed to be nil since no equipment is required for traditional mentoring. These figures (FY03 dollars) are summarized below.

Recurring Costs

Knowledge Manager (GS-14) half time	$ 88K
Materials, Training, & Travel	$ 15K
Total	$ 103K

Cost Analysis Summary. The results of this cost analysis are summarized in Table 3. The actual costs for a knowledge preservation program at ONI probably lie somewhere between the extremes listed in table 3. A "full blown" Sandia-like solution may be overkill for ONI's needs while the parametric estimates may omit some important costs. The value of this cost analysis is not in the absolute accuracy of its estimates, but by giving decision makers a "feel" for the magnitudes of the costs involved with fielding a knowledge preservation program.

Like the Sandia budget, the cost analysis presented here does not capture the costs for the analysts' time, normal HR support, and Information Technology (IT) network support because these costs are assumed to be accounted for elsewhere. If adequate funding cannot be obtained to fund a pilot solution like that described above, it may still be possible to pursue some

Table 3

Results of Cost Analysis for ONI Knowledge Preservation Solutions using Analogy, Parametric, and Rule of Thumb Methods (FY03 dollars).

Cost Category	"Full Blown" Sandia-Like Solution (Analogy)	"Scaled" Sandia-Like Solution (Analogy)	Digital Video Pilot Solution (Parametric)	Digital Video Pilot Solution (Rule-of-Thumb)	Learner-Built Case Studies (Parametric)	Traditional Mentoring (Parametric)
Recurring	$ 1,460K	$ 730K	$ 360K	$ 250K	$ 103K	$ 103K
Non-recurring	$ 3,163K	$ 1,521K	$ 125K	$ 125K	$ 0K	$ 0K
Total	$ 4,623K	$ 2,251K	$485K	$ 375K	$103K	$ 103K

knowledge preservation activities including videotaping of storytelling-interview sessions. Critical expertise-related knowledge could still be captured, but its effective use and transfer

would be limited until the supporting technology could be fielded and post-production activities could be performed.

The results in table 3 can be interpreted by defining a range of knowledge preservation solutions. These figures range from $478K to $691K in FY03 dollars. The low end is calculated by adding the rule-of-thumb estimate of $375K for a digital video to the parametric estimate of $103K for learner-built case studies. This low end estimate assumes no costs for traditional mentoring. The high end is calculated by adding the parametric estimate of $485K to the parametric estimates of $103K for both the learner-built case studies and traditional mentoring.

When compared with the costs for Sandia's knowledge preservation program, these costs seem affordable. However, costs should also be judged against the potential benefits from reducing the 6-8 years it takes to develop a top notch Naval intelligence analyst and increasing the overall quality of intelligence analysis.

Schedule. The schedule for implementing a knowledge preservation program at ONI depends on the resources that can be made available and the commitment of the organization to preserving knowledge. Some recent data suggests that some federal workers are retiring later than first projected (at the Social Security Administration, for example), but several of the senior analysts this author interviewed stated that they had firm plans to retire in 2003 and 2004.[159,160] The sooner a knowledge preservation plan can be put into action, the sooner expertise-related knowledge can start being preserved in a systematic process. A pilot project for digital video could be started in FY03 assuming project plans can be completed and funding can be obtained. The learner-built case studies could begin before FY03 assuming the learners and retiring experts

[159] "Reality Check," *Government Executive*, May 2002, p. 28.
[160] ONI Representatives, Interview by author, Suitland, MD, 3 April 2002.

can be identified. Traditional mentoring is already taking place at ONI. However, mentoring could be more formalized and more widely encouraged.

Cultural Acceptance. To understand the impact that culture and cultural acceptance have on the success of a knowledge preservation program, it helps to start by considering what is meant by culture.

> Culture is the combination of shared history, expectations, unwritten rules, and social mores that affects the behavior of everyone, from managers to mailroom clerks. It's the set of underlying beliefs that, while never exactly articulated, are always there to color the perception of actions and communications.[161]

"Culture is no more and no less than shared expectations," writes Roger Schank.[162] If culture is bound up in people's expectations, what expectations act as potential barriers to a knowledge preservation program? The most obvious barrier occurs when people have an information-hoarding versus an information-sharing attitude. Another barrier is erected when people have a sense of not being involved in the decision making process. Finally, another barrier appears when people are not motivated to participate in the process due to a perceived lack of value, difficulty of use, or an absence of long-term incentives. These expectational barriers appeared in the knowledge management lessons discussed in section IV, where the guidelines to adopt a knowledge-oriented culture and to use nontrivial motivational aids were discussed.

Although organizational cultures can be resistant to change, workers' expectations can be influenced by understanding and paying attention to the issues that drive their behavior. For example, a reluctance to share information can be caused by a worker's fear of job loss or loss of

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[161] Carla O'Dell and C. Jackson Grayson, Jr., *If We Only Knew What We Know: The Transfer of Internal Knowledge and Best Practice* (New York, NY: The Free Press, 1998), p. 71.
[162] Roger C. Schank, *The Connoisseur's Guide to the Mind: How We Think, How We Learn, and What It Means to be Intelligent* (New York, NY: Summit Books (Simon & Schuster), 1991), p. 42.

prestige. This issue can be addressed by rewarding workers who share knowledge and by fostering interdependence and taking steps to build trust between workers. Getting analysts involved in the planning stages of a knowledge preservation program and soliciting and acting on their feedback can lead workers to develop a sense of ownership in the process.

The issue of motivating analysts to participate in knowledge preservation activities can be addressed in several ways. For retiring analysts, emphasizing knowledge preservation as an opportunity for them to leave a legacy behind can provide a strong incentive for them to participate. Most of these analysts are eager to have their knowledge preserved, but they currently do not have the resources and the infrastructure at their disposal to easily make it happen. For junior analysts, the greatest motivation will come when they realize that their participation is helping them to do their jobs better. For both groups of analysts, a key spark that can ignite a self-sustaining knowledge preservation program is to make the process "***seem like fun***." One way to achieve this is to treat knowledge transfer exchanges, regardless of the mode, as *internal conversations*. Drawing from the ideas presented in section V:

> If we view conversations from without, as information being exchanged, they are not especially rich. But if we see them from within, as exformation, they can be *tremendous fun*. If you do not know the context, they can be dull. It is very boring to listen to people talking about someone you do not know. Such conversations tell you very little. But it is fun to talk about people you do know, whether personally or as public figures.[163]

The secret to making knowledge preservation seem like fun is to get people to really know each other—they need to develop meaningful relationships. How might this be accomplished when a newer analyst's only exposure to a retired analyst is through digital video clips and archived documents? One way is to record some interview sessions that capture the *personality* of the

[163] Nørretranders, *The User Illusion,* p. 96.

retiring analyst in addition to the structured storytelling sessions that are intended to capture expertise-related knowledge. Such interview sessions could include experiences from an analyst's youth and school days that shaped their career or inspired them. Anecdotes about an analyst's hobbies, favorite foods, and travel could be included as well.

Although I never met the physicist Richard Feynman, I feel like I know him by reading about his exploits where he fixes radios by thinking, cracks safes at Los Alamos, and plays bongos in Brazil.[164] Providing a sort of "biography channel" with similar content in addition to the expertise-related knowledge could also provide newer analysts with the same sort of window on the personalities of their retired predecessors.

This biographical background knowledge can be used to introduce newer analysts to the characters of retired analysts from whom they will be learning. This can serve to make the learning experience richer, more interesting, and therefore, more fun.

Knowledge Transfer and Competitive Positions. One potential barrier to knowledge transfer activities is the perception that special attention given to analysts, who have mentoring relationships or are building case studies with their senior counterparts, conflicts with civilian personnel policies on advertised competitive positions. One senior analyst interviewed by the author explained that this issue was raised in a Subject Matter Experts (SME) group meeting at ONI.[165]

One solution to this problem is to decouple knowledge transfer activities from the SME positions. While ad hoc activities, outside the auspices of a formal program, could possibly be

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[164] Edward Hutchings (Ed.), Ralph Leighton, and Richard P. Feynman, *'Surely You're Joking, Mr. Feynman!': Adventures of a Curious Character* (New York, NY: W. W. Norton & Company, 1997).

[165] ONI Representatives, Interview by author, Suitland, MD, 3 April 2002.

construed as favoritism, incorporating these activities as part of a career development program for analysts removes this concern. Identifying analytical competencies and career plans in writing are also in consonance with the analytical tradecraft process initiatives discussed earlier (see pages 87-89).

An approach similar to the one used in the *Civilian Career Path Guide* could be adopted to document "career foundational competencies" and provide assessment tools for Naval intelligence analysts.[166] Elements of this approach include:

- Job roles and competency lists[167]
- Assessment matrices[168]
- Career Progression Plans (CPP) or Individual Development Plans (IDP)[169]

Embedding knowledge transfer and preservation activities in a formal career development program for analysts has the advantages of setting written goals, providing an individual assessment mechanism, and documenting progress. The *Civilian Career Path Guide* provides the following advice with regard to career planning activities and competitive positions:

> Keep in mind that career planning activities do not guarantee promotion or advancement, but do enhance an employee's ability to advance or be promoted.[170]

Summary. In this section, specific answers have been developed and presented to the research questions raised earlier in the report. The nature of expertise in conducting Naval intelligence was discussed along with ideas on how to identify and prioritize expertise-related knowledge worth preserving. Interview techniques for eliciting knowledge and ideas for weaving stories and narratives around critical indices and cues were also presented. The benefits

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[166] Department of the Navy, *Civilian Career Path Guide*, pp. 35-36.
[167] *Ibid.*, pp. KM-1 through KM-5.
[168] *Ibid.*, pp. 35-36.
[169] *Ibid.*, p. 47.
[170] *Ibid.*, p. 47.

of a systematic process for archiving documents, files, and records were discussed along with how a document archiving process can complement a knowledge preservation program. The value of adopting a process orientation towards intelligence analysis was also discussed.

The ad hoc knowledge preservation initiatives being taken at ONI were discussed and ideas for incorporating these initiatives into the three-pronged knowledge preservation model were presented. Finally, the characteristics of what it takes for a practical knowledge preservation program was addressed by considering top concerns voiced by both analysts and ONI management. This discussion was followed by considering the issues of affordability, schedule, and cultural acceptance.

Affordability was addressed by adopting a simplified working definition and performing a cost analysis using analogies drawn with Sandia National Laboratory's knowledge preservation program. Additional cost estimates using parametric and rule-of-thumb cost estimate methods were also presented. The results from this cost analysis were then interpreted and set in a larger context by defining a range of options.

Schedule issues were addressed by discussing when various components of a knowledge preservation program could reasonably be put into action. Given a high priority, all components could be in place in FY03.

Cultural issues were addressed by discussion how culture translates into shared expectations and what can be done to remove cultural barriers to a knowledge preservation program and make it seem like fun. In the next section areas for future research are identified and concluding remarks are presented.

SECTION VII

CONCLUDING REMARKS

Areas for Future Study. There are a number of important issues which are outside the scope of the work presented in this study report. These issues are ripe for future study and answers to the questions they raise could greatly assist knowledge management programs at DoD in general, and ONI in particular. These issues include:

- **Assessment.** The best ways to assess and measure the effectiveness of knowledge preservation efforts are open questions. Is there a common method to assess learning and the effectiveness of expertise-related knowledge capture using a digital video archive, learner-built case studies, and traditional mentoring approaches?
- **Document Archiving**. The archiving of documents, files, and records was judged to be beneficial, but not essential, for the transfer of knowledge from one analyst's head to another. The value an electronic document archive can add to the knowledge preservation process should be studied.
- **Use of AI-based Tools.** Although Artificial Intelligence based tools are not yet capable of true knowledge preservation and transfer between people, products such as Tacit Knowledge System's KnowledgeMail offer new possibilities for identifying and selecting knowledge worth preserving. These tools should be studied and used if they can be shown to help select knowledge worth preserving.
- **Enterprise-Wide Knowledge Management.** How should knowledge preservation be integrated into an organization's overall enterprise-wide knowledge management program? Opportunities for leveraging resources and efforts should be studied and acted on.

- **Advanced Automated Analytic Tools**. The expertise-related knowledge captured in a knowledge preservation program represents a resource that can be tapped to create advanced automated analytic tools. These opportunities should be studied and efforts made to fully exploit this source of knowledge for the development of advanced automated analytic tools.
- **Phased Retirement.** Congress is considering legislation that would remove financial barriers to allow "phased retirement" where retired employees can work part-time and still receive their full annuities.[171] Initiatives such as phased retirement, part-time employment, or contract employment to make selected retired analysts with critical knowledge available for knowledge capture activities should be studied.

Conclusion. Despite the attention now being given to the problems of an aging workforce, preserving the expertise-related knowledge of seasoned workers before they retire remains a daunting task. The knowledge itself is difficult to capture and store in a form that can easily be absorbed and used by others. The time and resources that can be dedicated toward this problem are in limited supply. The argument presented in this study report is that these obstacles to knowledge preservation can be overcome by following a planned approach that makes the best use of the time available, uses stories and narrative to convey knowledge, and builds on the science of learning.

In this study report, questions about the nature of expertise, the transfer of expertise-related knowledge, and the practicality of potential solutions for a knowledge preservation program at the Office of Naval intelligence were examined. The answers to these questions led

[171] ERISA Advisory Council, "The Working Group Report on Phased Retirement," November 14, 2000. <http://www.dol.gov/dol/pwba/public/adcoun/phasedr1.htm> [May 10, 2002].

to the development of a three-pronged model for knowledge preservation and ideas for putting the model into action that leverage ad hoc ONI knowledge preservation initiatives. The issue of affordability was addressed through a cost analysis that provides some order of magnitude estimates for the cost of a knowledge preservation program at ONI. Barriers to knowledge preservation and transfer including cultural acceptance and civilian personnel policies were considered.

While important issues remain to be studied, enough is known to begin attacking the knowledge preservation problem at ONI. The theory, lessons, model, and analysis contained in this study report provide a basis for building a viable knowledge preservation program.

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